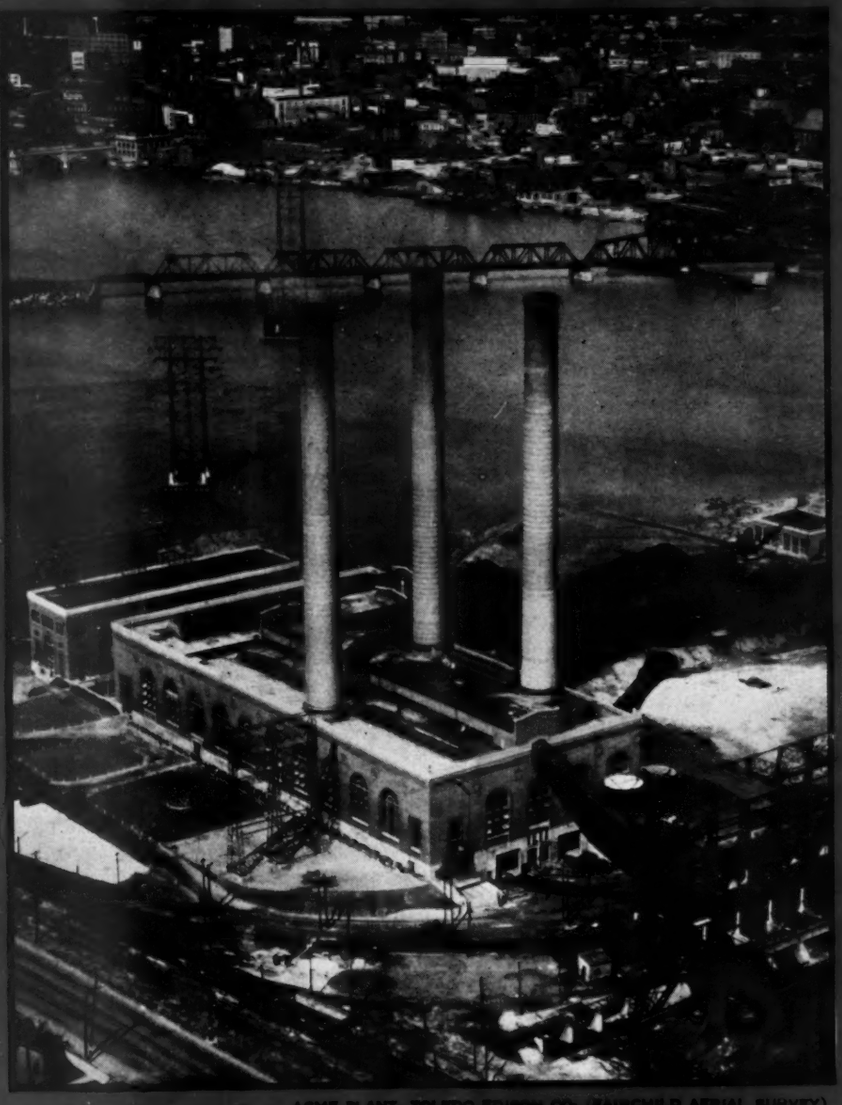
COMBUSTION

Vol. 2, No. 5 Engineering Library NOVEMBER 1930 NOV 4 1930 25c. a co



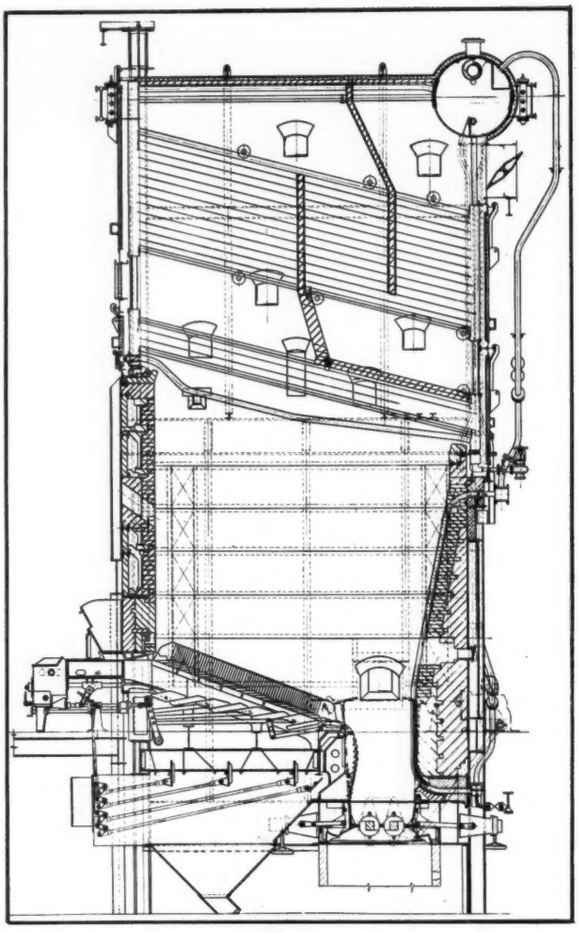
ACME PLANT, TOLEDO EDISON CO. (FAIRCHILD AERIAL SURVEY)

Tests of Welded Boiler Drums
By A. J. MOSES

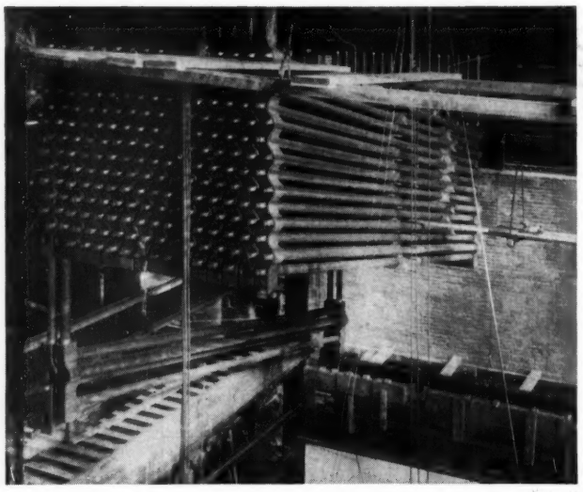
A Standardized Steam Generating Unit
By W. J. VOGEL

Other Articles in This Issue By

WM. L. DEBAUFRE • DAVID BROWNLIE • J. B. CRANE and A. C. FOSTER • B. J. CROSS



Sectional elevation of new Spokane Unit.



View of Walsh-Weidner boiler being assembled.

New Spokane Unit to equal output of six boilers now in use

The output of the steam generating unit now being installed at the Spokane Central Heating Company plant will equal the output of six boilers now in use and occupying three times the building volume.

The boiler is a Walsh-Weidner cross drum, straight tube, sectional header type, designed for 250 lb. pressure and contains 15,000 sq. ft. of heating surface.

The stoker is a twelve retort C-E Multiple Retort machine, 31 tuyeres long.

The front and side walls are air-cooled and the rear wall is composed of bare tubes to the clinker pit where the C-E Fin Tube construction begins.

The design of this unit is noteworthy as it involved fitting into the space available a unit capable of producing a large output, plus reliability of operation.

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE NEW YORK, N. Y.

BOILERS - AIR PREHEATERS - STOKERS - PULVERIZED FUEL EQUIPMENT - WATER-COOLED FURNACES

COMBUSTION

VOLUME TWO • NUMBER FIVE

CONTENTS FOR NOVEMBER, 1930

FEATURE EDITORIAL

The Industrial Power Plant — *by John H. Lawrence* 21

FEATURE ARTICLES

Tests of Welded Boiler Drums — *by A. J. Moses* 23

A Standardized Steam Generating Unit — *by W. J. Vogel* 31

Heat Engines and the Second Law of Thermodynamics — *by Wm. L. DeBaufre* 35

Exhaust Gas Boilers for Internal Combustion Engines — *by David Brownlie* 40

Direct Firing with Roller Mills and a Slagging Furnace — *by J. B. Crane and A. C. Foster* 44

How Areas of Heat Absorbing Surfaces are Computed — *by B. J. Cross* 48

Program of New Coal Research Laboratory of Carnegie Institute of Technology 50

What Constitutes "Immediate Loss or Damage" Within Terms of Boiler Insurance Policy — *by Leslie Childs* 52

EDITORIALS

Welded Boiler Drums Demand Recognition 22

Power Shows of Tremendous Educational Value 22

DEPARTMENTS

NEWS—Pertinent Items of Men and Affairs 51

REVIEW OF NEW TECHNICAL BOOKS 54

NEW EQUIPMENT—Simplified Belt Conveyor Carrier, New Mechanical-Drive Turbine, Natural Draft Gas Burner, Pyrometer Controller 56

NEW CATALOGS AND BULLETINS—A Review of Current Trade Publications . . 58

ADVERTISERS IN THIS ISSUE 63

CHARLES MCDONOUGH, *Business Manager* — CARL STRIPE, *Editor* — H. STUART ACHESON, *General Representative*

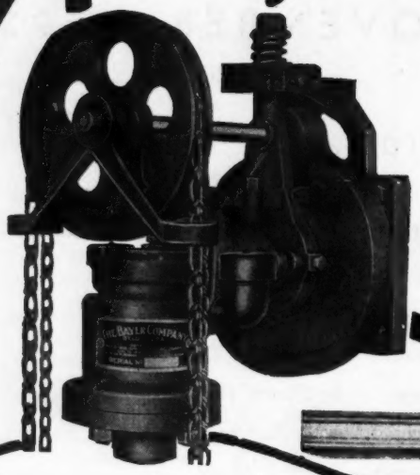
COMBUSTION is published monthly by In-Ce-Co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation, 200 Madison Avenue, New York. London office, Africa House, Kingsway, W.C. 2. W. R. Wood, President; George H. Hansel, Secretary; W. I. Branigan, Treasurer.

SUBSCRIPTIONS, including postage, United States and Canada, $2.00 a year, Great Britain 8 shillings. Other countries, $3.00. Single copies: United States and Canada, 25 cents.

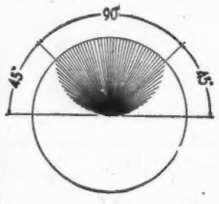
COPYRIGHT, 1930, by In-Ce-Co Publishing Corporation, New York. Printed in U. S. A. Publication office, 200 Madison Avenue, New York.

NUMBER OF COPIES PRINTED THIS ISSUE, 11,043

This is why you get Greater Cleaning Efficiency with BAYER Soot Blowers

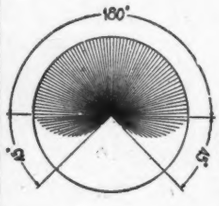


MASTER
MODEL "K-2"



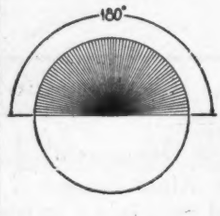
Delayed valve opening

This graph shows the action of steam from that type of blower in which the valve opens after the rotation of the element has begun. Fully one-half of the arc blown is used opening and closing the valve. This results in low pressure during these periods, and thereafter insufficient cleaning.



Premature valve opening

This second graph shows what happens when the attempt is made to bring the ordinary valve in the head blower (of graph above) up to required efficiency within 180° cleaning arc. Note the valve must open and close at 45° beyond the full arc, resulting in a 25% loss of steam.



Full blowing force properly directed

The above graph clearly illustrates the BAYER PRINCIPLE —in which the Bayer Valve opens wide, with full blowing force, a moment before the element begins to revolve, and closes the instant the element has ceased to rotate—giving a full-arc cleaning efficiency without loss of steam.

A BAYER for every type of boiler

BAYER CHROMITE

Non-Corrosive ELEMENTS

A complete understanding of the exclusive Bayer feature of *full blowing force properly directed* will show you just why Bayer Balanced Valve-in-Head Blowers do a better cleaning job with less steam, less time, and less wear.

In the Master Model "K-2" above, the valve though truly part of the Blower Head, is operated entirely independent of the rotating element. The controls are together in the operator's hands. Diagrams at the left show this Bayer principle insures full cleaning action with the minimum of steam used.

There are other Bayer features fully described in our new catalog that are well worth your consideration.

If you are interested in blowers for any type boilers, tell us your needs.

BAYER CHROMITE is our trade name for the Chromium Iron Alloy from which these blower elements are fabricated into continuous length of rolled tubing (not cast).

The heat resistance of CHROMITE combined with air-cooling produces a soot-blower element that is immune to oxidation and warping even when exposed to temperatures as high as 2650 degrees F.

Our experience with effective soot-blower installations may be of help to you. We will be glad to answer your questions.

THE BAYER COMPANY
1508 Grand Blvd., St. Louis, Mo.

COMBUSTION

Vol. 2 November 1930 No. 5

The Industrial Power Plant

JOHN H. LAWRENCE

MANY executives of industrial plants have no conception of the importance of their power plants. If they are in charge of the manufacturing end of the company, they will use every effort to cut down the cost of the product manufactured for sale, and will leave to a subordinate the details of the power plant and distribution systems. In many cases the subordinate is fully capable of handling his job, but in addition to operating the power plant this man, who is generally the master mechanic, also has the duty of keeping the manufacturing end of the plant in operation. The latter is a man-size job in itself in most plants.

I do not think that the first thing to be considered in an industrial plant is the power equipment, but it is a very essential part and one which can cost the owners much money and grief. Although the cost of power in such an establishment is generally only a small percentage of the total cost of operation, still in dollars and cents it very often runs into large figures. There are many industrials in this country that spend over a million dollars a year in their power plants, and a great many more spend over one hundred thousand dollars per year.

Expenditures like these are not to be ignored in this day of keen competition, and the executive will often find that big savings can be made by having his power plant in good condition and properly operated.

The ordinary master mechanic, with his nose to the grindstone all the time and with no opportunity for visiting modern installations to see the latest developments in the art, cannot be expected to keep up with the times.

The highest development in power plant engineering is found in the public utilities, and in that industry every opportunity is given to its engineers to become familiar with what is being done in other companies, by having them visit other plants and also by committees which interchange ideas on new developments and also comparative cost data.

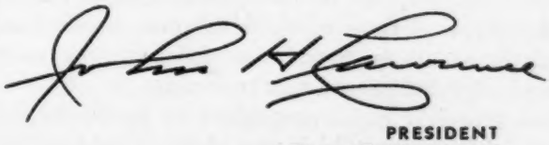
The executive of an industrial plant may say that it costs money to do this. This is true, but the returns are generally very great.

If the executive is not a power man himself, he should consult with others who are familiar with power plant practice. He may think that his power plant is operating satisfactorily if the manufacturing end is always furnished with the necessary power and steam. However, the dollars may be flying out of the windows twenty-four hours a day, when a revamping or the installation of new equipment might return from twenty to fifty per cent on the money spent.

This attitude of indifference on the part of the industrial executive not only applies to the condition of the power plant, but also to the personnel employed therein. In the average plant, any man who can shovel coal is considered qualified to be a fireman, and this same sort of rating applies pretty generally throughout the power plants of industrial establishments.

Power equipment costs money and can be ruined very quickly by careless operation, and careless operation results in low efficiency. Low efficiency means money wasted, and this is what the industrial executive is not supposed to have done around his plant.

A little thought given to the power end may frequently mean the difference between success and failure of a company.



PRESIDENT
Thomas E. Murray, Inc.

EDITORIAL

Welded Boiler Drums Demand Recognition

DISCARDED traditions are part of the price of progress.

Riveted steel boiler drums are as inadequate for the higher steam pressures of today as were the cast iron structures which they supplanted for the moderate pressures of yesterday.

The article describing tests of welded boiler drums, which is published in this issue of COMBUSTION, is significant of what may be a revolutionary trend in boiler manufacture. Like many new manufacturing techniques, the development of the fusion welded drum is the result of other important developments which have made riveted construction inadequate.

The wide adoption of higher boiler pressures has necessitated greater shell thicknesses, and in this respect the riveted construction is definitely limited. At these higher pressures, feed water problems become more complicated and infinitely more serious, and here, too, riveted drums fail to meet the requirements.

At the present time, the only satisfactory alternative constructions are fusion welded drums and solid forged drums. While the latter type of drum can be justified economically for very high pressures and large units, the fact remains that the process is highly expensive both from the standpoint of material and the time required for manufacture. Fusion welding, on the other hand, is practicable from an economic standpoint and, when properly applied, results in a construction that is definitely superior to that produced by any other method of fabrication.

However, the adoption of the welded drum construction with all its advantages cannot proceed until it is properly sanctioned by boiler codes and until specifications are established covering the manufacture and inspection of this method of drum fabrication. It follows, therefore, that the economic advantages of higher steam pressures cannot be fully realized until satisfactory codes covering welded vessels are established. Obviously, the adoption of such codes should be expedited as much as possible.

Until the practice of fabricating and inspecting welded drums is thoroughly developed, codified and standardized, every precaution should be taken to avoid faulty design and workmanship.

This may best be accomplished by establishing a system of licensing which would limit the building of welded pressure vessels to those manufacturers who have demonstrated beyond question the adequacy of their equipment and the ability of their processes and personnel to meet every code requirement.

Several manufacturers have long been engaged in research and development work which has resulted in the production of satisfactory welded, high pressure drums on a commercial basis. The incentive for this development lies not in the possibility of reducing manufacturing costs since welded drums are more costly to build than riveted drums. These pioneers have as their sole motive the desire to develop a pressure drum of superior quality and one which will be satisfactory for the modern range of steam pressures which are definitely beyond the limitations of riveted construction.

However, with increased production, the cost of manufacturing welded drums, which is even now within reasonable limits, will be still further reduced. to the general advantage of all users of steam power and particularly to those who can employ high pressures to advantage.

It is to be hoped that the several code committees will devote their earnest attention to this vitally important problem, so that satisfactory codes for welded boiler drums will shortly be established.

Power Shows of Tremendous Educational Value

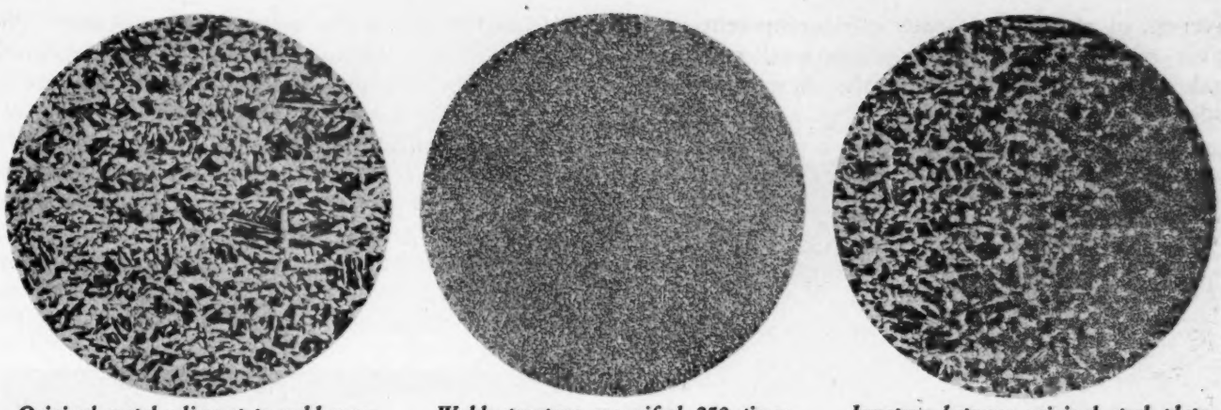
TWO important power shows and exhibitions are in the offing.

The Ninth National Power Show will be held at New York the first week in December and the Fifth Midwestern Engineering and Power Exposition will follow in February at Chicago.

The remarkable pace at which the entire power industry is moving ahead gives unusual significance to these two expositions. Over 500 manufacturers will display new equipment which represents the major progress in the power field during the past few years as well as designs and constructions projected for the needs of the future.

Coincident with these two exhibitions, technical meetings will be held under the sponsorship of leading engineering societies. Thus, the exhibitions and the technical sessions will supplement each other and will provide a remarkable opportunity for power engineers and executives to bring their knowledge of equipment and practices up-to-date.

Beginning with this year, each of these major power shows will be held on an every-other-year basis. Hence, the forthcoming expositions are expected to set records for attendance and for the number and attractiveness of the exhibits.



Original metal adjacent to weld magnified 250 times — a normal grain structure for steel boiler plates.

Weld structure magnified 250 times. Note exceedingly fine grain.

Juncture between original steel plate and weld metal showing excellent fusion and complete welding.

Fig. 1—Micro-photographs showing typical grain structure of original metal, weld metal and juncture of weld and base metal.

Tests of Welded Boiler Drums

The advent of higher boiler pressures with the attendant necessity for more effective feedwater treatment has introduced many serious problems, none of which is of more immediate importance than the method of drum fabrication. For pressures beyond the proper range of riveted construction, the fusion welding method appears to be the most practicable, providing the technique employed can be demonstrated to meet all the established safety requirements. In this article, the author presents the results of elaborate tests which would indicate that the particular process of welding used will meet every requirement of conservative practice. COMBUSTION believes that the welding of high pressure boiler drums is a development of first importance and is glad to have the opportunity of publishing this unusually valuable article.

By A. J. MOSES

Superintendent, Hedges-Walsh-Weidner Company
Chattanooga, Tenn.

THE rapidly increasing demand for high pressure boilers has presented to the manufacturer many difficult construction problems. One of the most important of these has to do with riveted joints. In many instances plate thickness requirements already have extended beyond the practical limits of satisfactory riveted construction. Manufacturers and other interested groups are now of the opinion that the adoption of welded seams in lieu of riveted joints, will prove to be the proper and economical solution of this problem.

Fusion welding, because of its proven adaptability to extreme plate thicknesses, appears to offer more advantages. But, in order to meet the necessarily rigid requirements, this method must be developed to a much higher efficiency than is being obtained in the ordinary practice of today. Because of the uncertain factors connected with welding, its application to the power-boiler field will necessitate very rigid testing of completed vessels. This in itself will evoke a host of problems pertaining to the design, shape, etc. of various parts of the structure.

Over a considerable period of time the Hedges-Walsh-Weidner Company, has been pursuing an investigation of the application of welding to power-boiler drums. This study, while by no means considered complete, has yielded very satisfactory results which justify full confidence in the process developed for manufacturing welded pressure vessels to meet the most severe requirements.

This investigation has comprised three stages: (1) a preliminary study leading up to a choice of method: (2) experimental and development work with the chosen method: (3) practical application and tests of the developed process. The metallic arc welding process was chosen as being the most suitable in view of the nature of the work and the requirements contemplated. The second stage or the development of a reliable procedure of metallic arc welding may be considered as being practically completed. The third stage has just begun, only two practical tests having been made up to the present time. While admitting that the results of two such experiments will not be accepted as conclusive, the comprehen-

siveness of the second stage of development work gives added weight to these practical tests, and makes a publication of the results therefrom justifiable at this time.

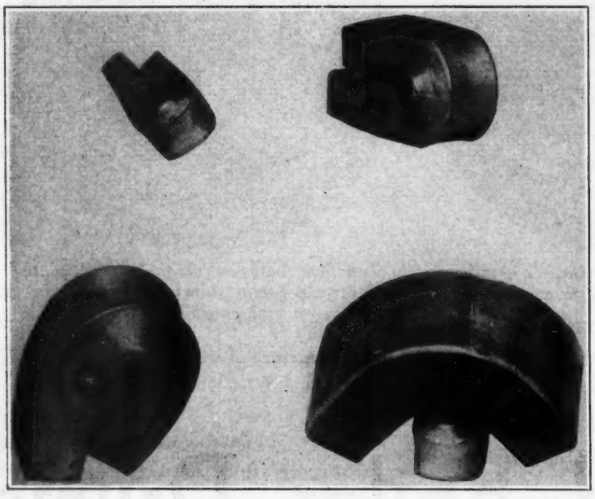


Fig. 2—Samples of weld bent cold showing 60 per cent elongation of outside fibers. Charpy impact tests showing minimum value of 20 ft. lb.

In the process of developing a satisfactory weld, a high standard was adopted. This standard was the attaining of a welded joint as good in every respect as the base material or boiler plate. After many disappointments, this goal was reached and held. During the early stages of this work, no code or specifications of sufficient severity had been published. Since that time the A.S.M.E. Boiler Code Committee has proposed a set of tentative specifications which on the whole appear to cover all requirements. The test results obtained check with these proposed specifications most satisfactorily.

The experiments performed during this period consisted of the welding of small plates of various thicknesses, using different electrodes and methods of application. Sample coupons cut from these plates were subjected to bend, impact and tension tests as well as micro and chemical analyses. Photographs

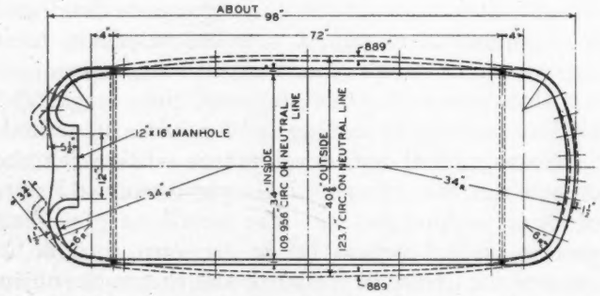


Fig. 3—No. 1 test drum; solid lines show drum before test, dotted lines after test.

of some of these samples are shown in Fig. 2. Microphotographs showing typical grain structure of original metal, weld metal and juncture of weld and base metal are shown in Fig. 1. These particular micrographs were obtained from sample specimen cut from the No. 2 test drum discussed later. The exceedingly fine grain structure of the deposited metal and the excellent fusion shown at juncture of weld and base metal are of particular interest. Perfect fusion leads to the foundation of grains which partake of both the base and deposited metal. Micrographs of weld juncture clearly show this grain formation. These tests, while not so spectacular as a destruction test of a completed structure, are thoroughly reliable and are much more suitable for research investigations. Almost instantly available

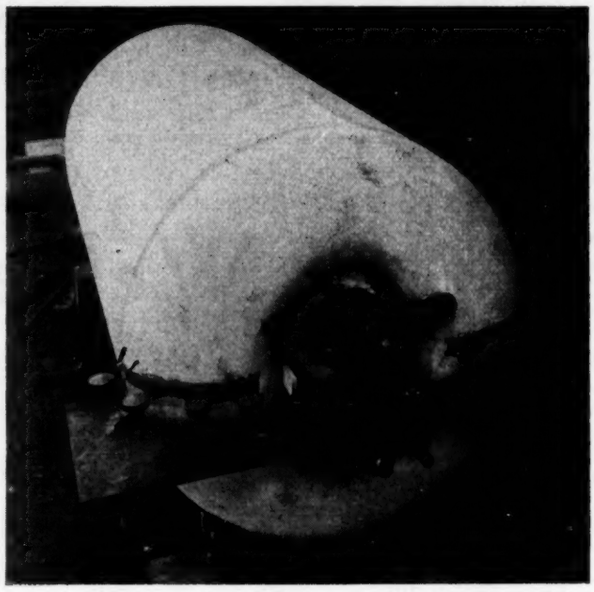


Fig. 4—No. 1 test drum before test showing instruments for measuring changes in shape. Circumferential expansion was indicated by means of music wire wrapping around shell and connected to indicating scales.

diagnoses permit of rapid changes in procedure and hence eliminate much lost time and energy. It was considered that a thorough mastery within the scope of these tests was essential in order to reduce to a minimum the number of the more expensive and tedious experiments on full size drums. A process was developed which unfailingly gave good results. As a test of its reliability, one hundred samples were welded, all of which fully withstood all applied tests.

Having attained this stage, entrance into the field of practical application to full size test drums was considered warrantable. It was thought advisable that these test drums should be exact replicas of actual boiler drums in order to make a study of the weld seams and the design in general under two dimensional stresses. Also it was thought very necessary that welded drums be stress relieved and then subjected to a hydrostatic test sufficient to set up stresses of at least 22,000 lb. per sq. in. In order to withstand such high test pressures, many features of accepted design such as head shapes, thicknesses and manhole and other opening reinforcements required further investigation. Therefore it was considered de-

sirable to test some of these drums to destruction in order to ascertain the weak points in present day designing. From the nature of the problems involved, these tests were intended to have, and do have, a progressive relation. Hence it appears advisable that a discussion of these should be taken up in the order made.

Number 1 Test

Naturally the main objective in this first experiment was an investigation of the strength of the welded seams when subjected to two dimensional stresses. Inasmuch as one man-hole opening was desirable, provisions were made to study changes in shape of both blank and man-hole heads. The material used in shell and heads was ordinary boiler plate steel of firebox quality and of 55,000 lb. per sq. in. minimum T.S. The shell was of 1 in. plate, 34 in. I. D. and 72 in. long between head weld seams. Solid lines in Fig. 3 show a section of this drum before test, giving all dimensions.

In fabricating, three weld seams were used,—two circumferential or head seams and one longitudinal seam. With the exception of one inner bead, all metal was deposited from the outside, the welding groove extending from the outside to within 1/8 in. of inner surfaces of plates. The seams were first tack welded, then completed. All contraction stresses were locked up and later relieved by annealing the completed structure at about 1250 deg. fahr.

The A.S.M.E. proposed specifications for such work allows only 80 per cent efficiency to the welded seams. In accordance with this rule, the allowable working pressure on this drum would be 517 lb. per sq. in. If 100 per cent efficiency or 55,000 lb. T.S. were allowed to the deposited metal then the W.P. would be 648 lb. The W.P. permitted for the 1½ in. blank and man-hole heads, computed from the new formulas in the A.S.M.E. Boiler Code are 583 lb. and 506 lb. respectively.

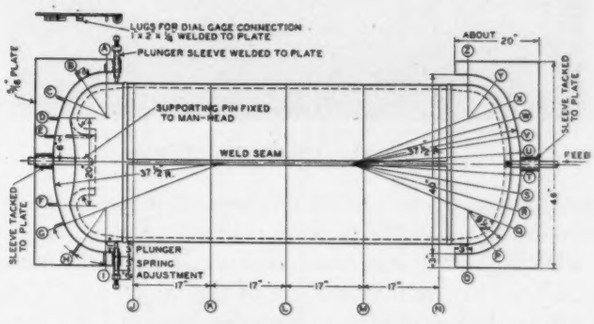


Fig. 5—Diagram of No. 1 test drum showing lettered points at which measurements were taken.

The test consisted in the subjection of this drum to increasing hydrostatic pressures up to failure. Between each application the pressure was dropped to zero in order to note any permanent set. Fig. 4 is a photograph of No. 1 test drum showing arrangements for taking measurements. The vessel was given a light coat of lime wash to indicate highly stressed areas in the order of their appearance. Fig. 5 gives in diagram the scheme of taking measurements. Letters are used in this diagram to indicate those points at which these measurements were taken. Tables and curves give the data concerning these various points. All readings were taken with the

TABLE I
Data—No. 1 Welded Drum Test
Date of Test. May 2, 1930. Diam. of Drum I.S. 34 in. Thickness of Shell 1 in. Thickness of Heads 1½ in. Radius of Dished Heads 34 in. Overall Length of Drum about 98 in.

Pressure lb. per sq. in.	GAGE READINGS ON HEADS (Deflections "Inches")																					Circumferences (Elongations "Inches")				
	A	B	C	D	E	F	G	H	I	O	P	Q	R	S	T	U	V	W	X	Y	Z	J	K	L	M	N
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	0	0	.004	.0085	–	.0075	.0026	—.0005	0	.004	—.001	.005	.007	.007	.006	.007	.004	.003	—.001	—.002	—.004	0	0	0	0	0
0	0	0	.0028	.0025	–	.0005	.0025	.002	.001	.006	.005	.005	.003	.003	.001	.001	.001	0	0	—.001	—.001	0	0	0	0	0
500	0	0	.0065	.015	–	.0125	.005	—.0008	0	.003	.002	.003	.006	.010	.009	.007	.007	.004	—.004	—.003	—.003	0	0	0	0	0
0	.0015	.0015	.0025	.0015	.0015	0	.0015	.001	.0015	.005	.005	.003	.004	.002	—.001	—.001	0	0	—.001	—.002	—.002	0	0	0	0	0
775	0	.0015	.0108	.023	.0395	.021	.008	— .001	0	.003	.001	.001	.007	.013	.011	.012	.012	.006	—.005	.004	—.004	0	0	0	0	0
0	.0015	.0018	.0025	.002	.0019	.0004	.0022	.0015	.0015	.005	.002	.002	.002	.001	—.001	.003	—.001	.002	—.005	—.004	—.004	0	0	0	0	0
1000	0	.0005	.0145	.032	.0571	.0323	.014	.0002	0	.003	—.001	.003	.009	.016	.016	.017	.016	.009	—.003	—.007	—.007	0	0	0	0	0
0	.0013	.0015	.0038	.0035	.006	.002	.0028	.0015	.0013	0	.002	.004	.002	0	—.001	—.001	—.001	—.003	—.004	—.004	—.004	0	0	0	0	0
1250	0	.0016	.0253	.060	.1166	.062	.0248	.0005	0	.002	—.001	.002	.011	.019	.019	.021	.019	.010	—.003	—.008	—.008	0	.0156	.0078	0	0
0	.0025	.0032	.012	.0272	.0545	.0268	.012	.0038	.0025	.005	.002	.001	.002	0	—.004	—.004	—.002	—.003	—.005	—.005	—.006	0	0	0	0	0
1500	.0218	.0225	.0515	.3084	.710	.308	.0495	.0205	.0218	.002	.002	.002	.012	.023	.024	.024	.021	.012	—.005	—.005	—.007	.0156	.0313	.0156	0	.0078
0	.0245	.031	.0495	.2772	.647	.2768	.0495	.033	.0248	.004	.002	0	0	0	—.005	—.004	—.003	—.005	—.007	—.007	—.006	0	0	0	0	0
1750	.0295	.031	.159	.543	1.007	.527	.1745	.0408	.0295	.001	—.005	.002	.017	.030	.032	.032	.029	.017	—.005	—.015	—.018	.0625	.8125	.5625	.625	.125
0	.0308	.031	.159	.496	.960	.496	.1433	.0486	.031	0	—.003	—.001	.004	.006	.003	.003	.002	.002	—.005	—.009	—.010	.0625	.8125	.5625	.625	.125
2000	.031	.031	.2215	.668		.684	.2213	.0096	.031	—.001	—.005	—.003	.022	.035	.039	.041	.036	.020	—.005	—.016	—.011	.1875	1.219	1.031	1.0625	.3125
0	.035	.031	.2215	.668		.668	.2057	.0409	.035	0	—.004	0	.005	.006	.008	.008	.008	.005	—.005	—.008	—.008	.1875	1.219	1.031	1.0625	.3125
2250																						.406	1.875	1.719	1.78	.609
2500																						.719	2.75	2.562	2.625	1.000
0	.0313	.031	.4245	1.168		1.168	.4717	.1189	.0313	—.003	.003	—.006	.034	.067	.078	.088	.078	.048	.008	—.010	.011	.719	2.75	2.562	2.625	1.000
2750																						1.125	4.031	3.812	3.812	1.56
0	.0625	.078	.4245	1.449		1.512	.5967	.1189	.0625	.012	.059	.010	.106	.195	.236	.262	.238	.147	.019	.034	.024	1.125	4.031	3.812	3.812	1.562
3000																						1.75	5.812	5.937	5.78	2.344
0	.0625	.1093	.706	1.824		1.903	.722	.1189	.0625	.036	—.053	0	.193	.334	.352	.390	.354	.211	0	—.091	—.004	1.75	5.812	5.937	5.78	2.344
3250																						3.063	11.688	13.688	11.812	3.938
0	.0625	.1563	.856	2.562		2.562	.948			.072	—.069	—.014	.245	.435	.485	.494	.449	.267	.026	—.139	—.006	3.063	11.688	13.688	11.812	3.938

NOTE. All outward changes not marked. All inward changes marked (—).

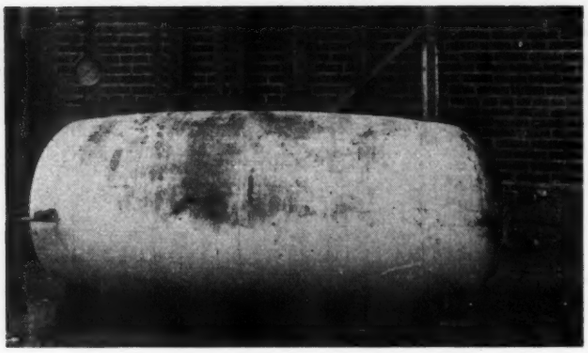


Fig. 6—No. 1 test drum after test.

pressure on, up to 2000 lb. Above that only zero or permanent set readings were taken.

Flaking of the lime wash first occurred on the man-hole head at the intersection of the major axis with a circle drawn midway between points "B" and "C", Fig. 5. This flaking occurred at about 1250 lb. pressure, and spread rapidly around and inward with the next application of pressure. At 1750 lb., flaking began to appear on the barrel between the points "K" and "M". An ordinary soft gasket was used on the man-hole seat. The man-head and rolling edge of man-hole seat cut through this gasket, effecting a metal to metal joint which remained absolutely tight up to 3250 lb. The arch bolts were tightened with the pressure on at each increase in pressure. When the pressure was lowered after attaining 3250 lb., this metal to metal seat was disturbed causing such serious leakage that it was impossible to continue with the test.

Fig. 6 shows a photograph of this drum at the completion of the test. Table I gives the recorded data for this test. Figs. 7 and 8 are pressure-deflection and pressure-elongation curves plotted for those points showing maximum changes. Table II gives results of measurements taken across the longitudinal weld seam and measurements taken in the same direction, over the same distance adjacent, but not across the weld seam. It also gives the elongation of shell measured between tangent points on the knuckle radii of the heads.

Dotted lines in Fig. 3 give the shape and dimensions of the drum after this 3250 lb. hydrostatic pressure test. The behavior of the shell and longitudinal weld was very satisfactory. After the test, no marked evidences of distress were visible in either the weld or boiler plate. Two or three surface defects were found in the deposited metal, and several such defects, longer in extent, were noticed in the shell plate away from the weld area. Reference to data given in Table I, shows that a permanent set took place in the shell between 1500 lb. and 1750 lb. pressure. Interpolating that this occurred at 1625 lb. pressure then permanent set occurred at 2½ times a working pressure of 650 lb. based on a 100 per cent joint. Then too, according to the ordinary design formula, an internal pressure of 3250 lb. sets up hoop tension stresses in a cylinder 38-3/8 in. I.D., amounting to 62000 lb. per sq. in. This gives a factor of safety in excess of 5 based on a 100 per cent joint. In this connection, it is of interest to note from Table II that the elongation of the deposited metal was practically equal to that of the boiler plate.

The performance of the blank head was very good.

TABLE II.
DATA—No. 1 WELDED DRUM TEST

Date of test May 2nd, 1930.
Diam. of Drum I.S. 34 in. Thickness of Shell 1 in.
Radius of Dished Heads 34 in. Overall Length about 98 in.
Thickness of Dished Heads 1½ in.

Pressure Pounds per sq. in.	Stretch Across Weld (in.)	Stretch Outside Weld (in.)	Elongation of Drum	
			Along Top (in.)	Along Side (in.)
775			1/128	1/128
0			0	0
1000			1/128	1/128
0			0	0
1250	1/128		3/128	3/128
0	0		0	0
1500	1/64	1/64	1/32	1/32
0	0	0	0	0
1750	5/64	5/64	1/16	1/16
0	5/64	5/64	1/64	0
2000	5/64	3/32	1/8	0
0	5/64	3/32	3/32	—1/32
2500		0		
0	13/64	7/32	3/32	—1/32
2750	15/64	15/64	1/8	—1/32
3000	15/64	15/64	3/16	0
3250				
0	11/32	25/64	5/16	0

NOTE: All inward changes marked (—).

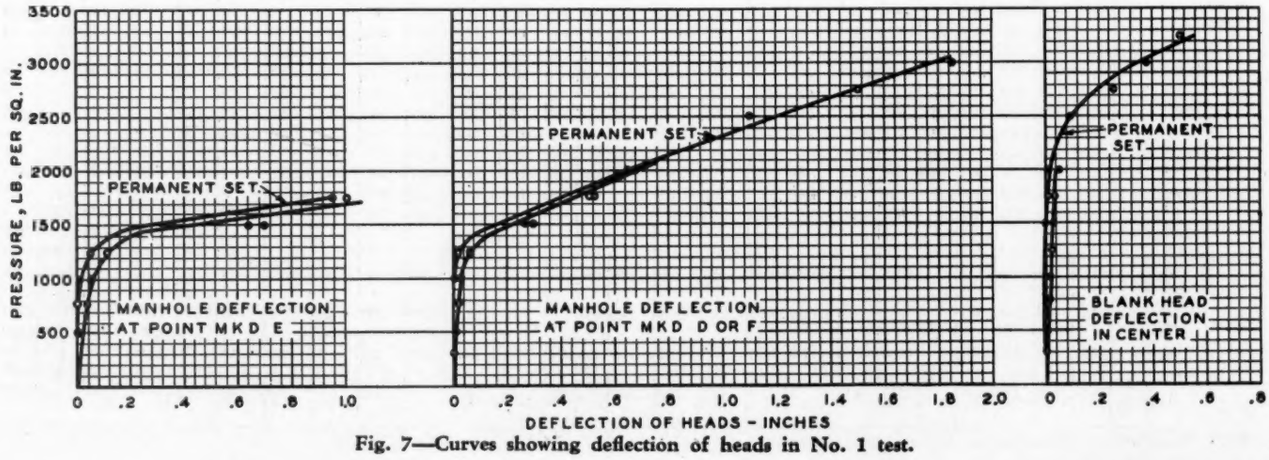


Fig. 7—Curves showing deflection of heads in No. 1 test.

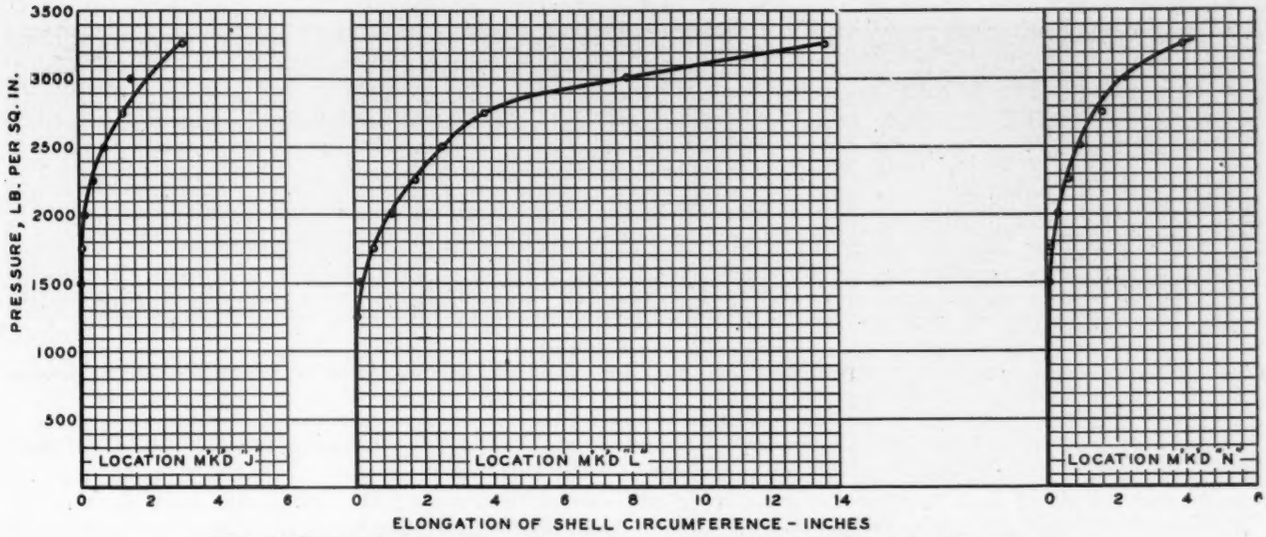


Fig. 8—Curves showing elongation of welded drum shell circumference in No. 1 test.

A reference to curves in Fig. 7 will show that permanent set first occurred at 2000 lb. pressure. This indicates that the A.S.M.E. Code formula for blank heads is very conservative. In fact, based on the same ratio of permanent set pressure to W.P., namely 2½ times, a W.P. of 800 lb. should be permissible for a head of this size, shape and thickness.

The distortion of the man-hole head proved to be the most surprising feature of this test. Fig. 3 best shows the extent of this. At 3250 lb. pressure, the only movement occurring was at this point. The

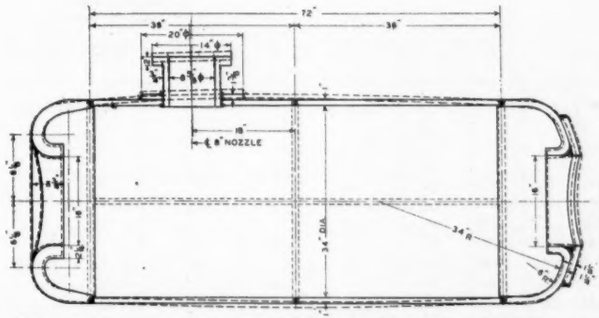


Fig. 9—No. 2 test drums; solid lines show drum before test, dotted lines after test.

rounded inner edge of the gasket surface was formed in rolling against the man-head under pressure. The breaking of the metal to metal joint at this point was the cause of the termination of the test. Curves in Fig. 7 show that the first permanent set in this head occurred between 1000 lb. and 1250 lb. pressure and probably at about 1200 lb. Using as a basis the same ratio of 2½ times, gives a W.P. of only 480 lb. Therefore this head falls short in an attempt to design a vessel of equal strength throughout. The W.P. of 480 lb. is only slightly less than the 506 lb. W.P. allowed by the use of the A.S.M.E. Code formula applied to this head. But evidently it would not be safe to use this formula in the design of man-hole heads for vessels to be subjected to very high test pressures.

Number 2 Test

In the light of information gained from the first test, the second test was planned. No increase in shell thickness was considered desirable until after a good uniform design was accomplished. But a more strenuous test of the weld seams was desired. Hence the new drum was designed to have two courses, with a girth seam weld in the center and with the two longitudinal weld seams placed in line. Also, in addition to the high hydrostatic pressure test it was planned to subject this drum to the A.S.M.E. Code proposed fatigue test of 1000 cycles of pressure varying from 0 to 1½ times the working pressure.

No further investigation of blank heads for this particular size drum being necessary, man-hole heads for both ends were planned. One was to be a regulation A.S.M.E. Code head designed for a W.P. in excess of that calculated for a longitudinal joint efficiency of 100 per cent. The other was to be of special design, using thinner plate and reinforcement around opening sufficient to replace effective material removed and sufficient to diffuse the concentrated stresses around this opening to a degree commensurate with the stresses set up in other parts of the vessel. A problem of similar nature was proper reinforcement of a nozzle opening placed in the shell.

In accordance with this plan, No. 2 test drum, as shown with dimensions in Fig. 9, was designed and fabricated. The material, general dimensions and method of fabrication followed those of the first test drum with the exception of those changes and additions already mentioned. Calculations based on the same formulas as were used in previous test give for the drum shell a W.P. of 517 lb. based on a joint efficiency of 80 per cent or 648 lb. based on a joint efficiency of 100 per cent. They give a W.P. of 760 lb. for the 2¼ in. man-hole head. The special reinforced man-hole head and nozzle were designed for 650 lb. W.P.

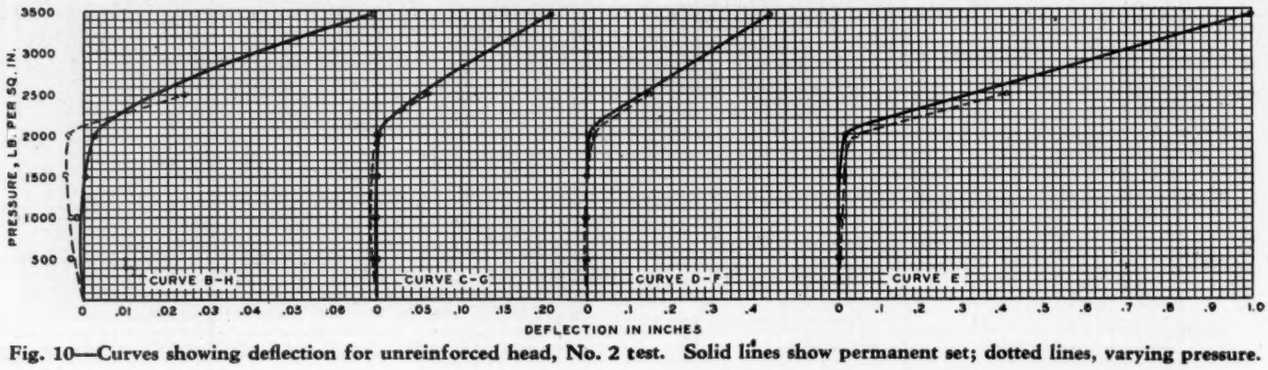


Fig. 10—Curves showing deflection for unreinforced head, No. 2 test. Solid lines show permanent set; dotted lines, varying pressure.

This drum was stress relieved in the manner already described. It was then given a light coat of lime wash and subjected to a fatigue test consisting of 10000 cycles of pressure applications varying from 0 to 778 lb. No measurements were taken during this test. No flaking of the lime wash occurred and no evidence of distress was found afterwards. Upon the completion of the 10000 cycles, the drum was subjected to a hydrostatic test identical with that imposed on No. 1 drum. Lettered diagram in Fig. 11 indicates the points where measurements were taken.

First flaking of the lime wash occurred on the 2¼ in. head between points "A" and "B" and at 2000 lb. pressure. This flaking spread rapidly inward with increase of pressure. Slight flaking occurred on the barrel and side of nozzle neck at 2250 lb. pressure. Slight flaking also occurred on the knuckle radius of the 1¼ in. reinforced head at about this same pressure. This latter cracking of the lime wash traveled slowly in the direction of the head weld seam with increase of pressure. The man-hole reinforcing plate indicated very little disturbance up to completion of test. The flange of the reinforced head, being of comparatively light plate, followed the expanding contour of the drum shell. The flange of the unreinforced head, being of much heavier plate

TABLE III

Data—No. 2 Welded Drum Test

Date of Test, June 18, 1930. Diameter of Drum I.S. 34 in. Radius of Dished Heads 34 in. Thickness of Dished Heads, unreinforced—2¼ in., reinforced 1¼ in., with 1¼ in. P.L. Overall Length of Drum about 98 in. Thickness of Shell 1 in.

Pressure lb. per sq. in.	GAGE READINGS ON HEADS (Deflections "Inches")																		Circumferences (Elongations "Inches")				
	A	B	C	D	E	F	G	H	I	O	P	Q	R	S	T	U	V	W	X	Y	Pressure lb. per sq. in.	J	K	L	M	N
0		3.4765	3.476	3.471	3.555	3.503	3.462	3.469		0	3.475	3.490	3.478	3.504	3.480	3.459	0				Zero Readings					
500		.481	.481	.476	.556	.511	.472	.478		0	.4745	.4867	.4725	.4995	.4815	.4615	0				0	0		0	0	0
0		.476	.477	.471	.548	.504	.464	.471		0	.472	.4885	.478	.505	.483	.461	0				500	0		0	0	0
1000		.476	.481	.475	.544	.506	.473	.473		0	.475	.487	.464	.491	.480	.4625	0				0	0		0	0	0
0		.473	.476	.471	.548	.502	.465	.475		0	.473	.4855	.478	.505	.4815	.4595	0				1000	0		0	0	0
1500		.476	.478	.471	.539	.503	.469	.478		0	.472	.477	.4555	.4825	.480	.4665	0				0	0		0	0	0
0		.473	.473	.472	.550	.502	.464	.472		0	.475	.492	.480	.575	.4825	.4605	0				1500	0		1/32	0	0
2000		.475	.475	.462	.512	.471	.463	.478		0	.4753	.481	.446	.4733	.475	.4635	0				0	0		1/32	0	0
0		.473	.473	.465	.535	.470	.460	.468		0	.477	.4895	.479	.5095	.4825	.4595	0				2000	0		1/16	1/64	0
2500		.449	.406	.330	.149	.345	.407	.448		.00015	.473	.468	.4145	.445	.477	.488	.00015				0	0		3/64	1/64	0
0																					2500	1/16		1¼	53/64	11/32
3450																					0	0		0	0	0
0		.423	.266	.050	2.560	.045	.255	.384		.00115	.548	.4015	.1225	.1615	.399	.541	.00115				3450	7/8		4 11/16	3 25/32	2 5/16
																					0	0		0	0	

	Zero Readings														Average Readings Pressure Curves							
															Press. lb. per sq. in.	B-H	C-G	D-F	E	P-U	Q-T	R-S
0	0	0	0	0	0	0	0		0	0	0	0	0	0								
500	—.0045	—.005	—.005	—.001	—.008	—.010	—.009		.0005	.0033	.0055	.0045	—.0015	—.0025	0	0	0	0	0	0	0	0
0	.0015	—.001	0	.007	—.001	—.002	—.002		.003	.0015	0	—.001	—.003	—.002	500	—.0068	—.0075	—.0065	—.001	—.001	.0009	.005
1000	.0005	—.005	—.004	.011	—.003	—.011	—.004		0	.003	.014	.013	0	—.0035	1000	—.0018	—.0080	—.0035	.011	—.0018	.0015	.0135
0	.0035	0	0	.007	.001	—.003	—.006		.002	.0045	0	—.001	—.0015	—.0005	1500	—.0043	—.0045	0	.016	—.0023	.0065	.022
1500	.0005	—.002	0	.016	0	—.007	—.009		.003	.013	.0225	.0215	0	—.0075	2000	—.0038	0	.0205	.043	—.0024	.007	.0314
0	.0035	.003	—.001	.005	.001	—.002	—.003		0	—.002	—.002	—.071	—.0025	—.0015	2500	.0243	.0630	.1495	.406	—.014	.0125	.0613
2000	.0015	.001	.009	.043	.032	—.001	—.009		—.0003	.009	.032	.0307	.005	—.0045	Permanent Set Curves							
0	.0035	.003	.006	.020	.033	.002	.001		—.002	.0005	—.001	—.0055	—.0025	—.0005	0	0	0	0	0	0	0	0
2500	.0275	.070	.141	.406	.158	.055	.021		.002	.022	.0635	.059	.003	—.029	500–0	—.0003	—.0015	—.0005	.007	.0005	—.0008	—.0005
0															1000–0	—.0013	—.0015	.0005	.007	.0008	.0015	—.0005
3450															1500–0	.0003	.0005	0	.005	—.0008	—.0023	—.0365
0	.0535	.210	.421	.995	.458	.207	.085		—.073	.0885	.3555	.3425	.081	—.082	2000–0	.0023	.0025	.0195	.020	—.0013	—.001	—.0033
															3450–0	.0693	.2085	.4395	.995	—.0775	.0848	.349

NOTE. All outward changes not marked. All inward changes marked (—).

resisted this change, thus setting up a bending moment around the head weld area. This caused a circumferential cracking of the lime wash around the drum at this location. At 3450 lb. pressure leakage in pipe connections and nozzle gasket ended the test.

The photograph shown in Fig. 12 was taken after completion of test. It shows very clearly the condition of the drum and extent of lime wash cracking at that time. Dotted lines in Fig. 9 give the shape of this drum at the expiration of test. Table III gives the recorded and averaged data and Figs. 10, 13 and 14 are the pressure-deflection and pressure-elongation curves plotted from this data. No evidence of distress was to be noted in any of the weld seams after the imposition of 3450 lb. hydrostatic pressure. After repair-

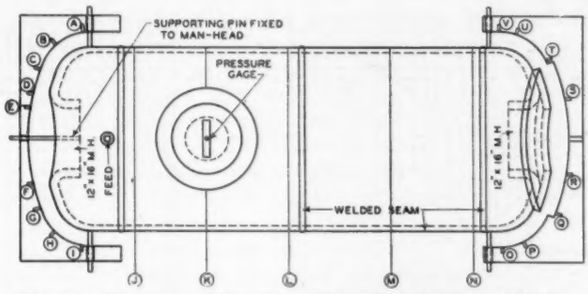


Fig. 11—Diagram of No. 2 test drum showing lettered points at which measurements were taken.

ing the leaks, it was decided to repeat the fatigue test on this drum. 10100 cycles of pressure were applied as before with no apparent effect.

Permanent set occurred in the shell at point "L" at 2000 lb. pressure. This is several hundred pounds higher than the corresponding point on No. 1 test. Explanation of this lies in the possible reinforcing effect of the girth seam weld and in the higher elastic limit of the boiler steel used. Mill Test reports show a 6000 lb. higher T.S. for the latter drum steel. This may also explain the lesser total elongation. According to the design formula, the internal pressure of 3450 lb. sets up hoop tension

Fig. 12—View of No. 2 test drum after test showing flaking at unreinforced head end.

stresses in the cylinder where expanded to 35½ in. I.D., amounting to 61300 lb. per sq. in., giving a factor of safety in excess of 5.

The knuckle radius of the reinforced head took a permanent set inward at about 2250 lb. pressure, as shown in curve for points "P-U", Fig. 13. Curves for all points on the unreinforced head indicate a permanent set at 2000 lb. pressure. On account of the hurried nature of this test, it being imposed before the members of the "National Board of Boiler and Pressure Vessel Inspectors", no niceties were attempted such as taking strain gage measurements around the nozzle reinforcement. No measurements were taken at that point but the observed action of the lime wash was proof of the sufficiency of the design.

As before stated, it is not considered that the scope and number of tests made, are a sufficient basis on which final conclusions can be drawn. But further immediate tests are contemplated, based on what may be termed final or semi-final conclusions These may be enumerated as follows:—

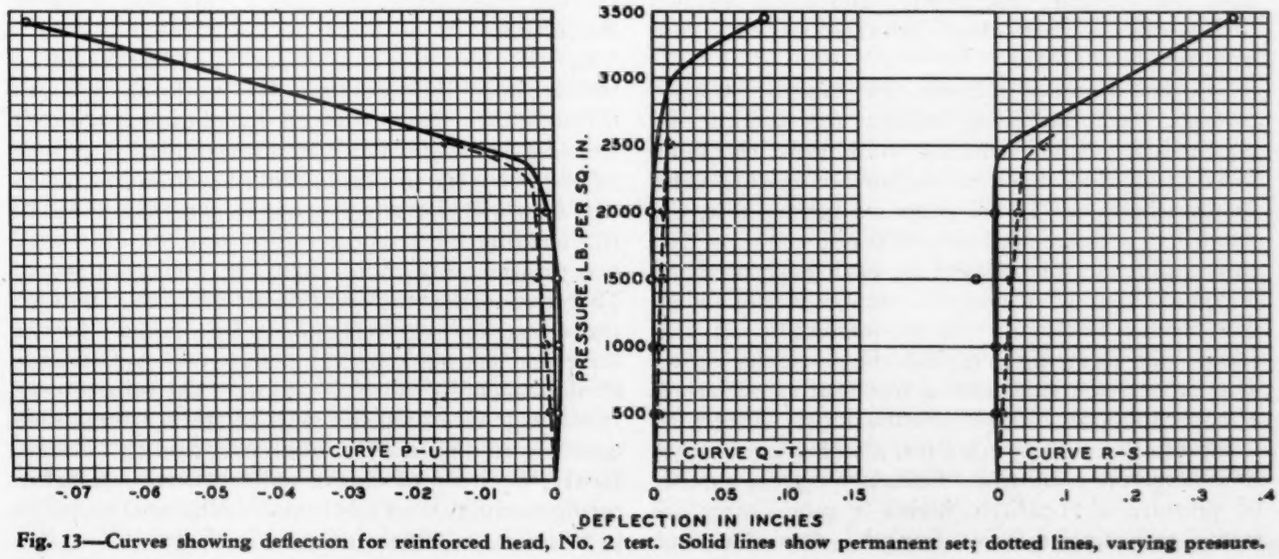


Fig. 13—Curves showing deflection for reinforced head, No. 2 test. Solid lines show permanent set; dotted lines, varying pressure.

(1). The process of metallic arc welding developed by the Hedges-Walsh-Weidner Company is safely applicable to power-boilers and pressure vessels. It has met all the requirements of the proposed A.S.M.E. Code without exception in numerous welded coupon tests and in two demonstrations with full size drums. A factor of safety in excess of 5, based on 55000 T.S., was obtained in all cases. Hence a joint efficiency of 100 per cent was proven, whereas, only 80 per cent is allowed by the proposed specifications.

(2). Thorough stress relieving of completed welded structures is a necessary supplement to a satisfactory welding procedure. Also the annealing benefits extend to other than welded parts of the structure. As an example of this, the action around the man-hole in No. 1 test is worthy of note. There are other tests on record wherein actual failure of the plate by cracking occurred at this point. In those cases where low carbon boiler plate steel was used, such failures were doubtless due to the unavoidable stresses left from the flanging operation. Annealing removes such stresses and also those connected with the cold bending of shell plates.

(3). The evidence indicates that high hydrostatic pressure tests producing stresses approaching the elastic limit of the material, will prove the more satisfactory and practical method of testing completed structures. In the proposed fatigue test, the number of pressure applications is not sufficient. Ten thousand cycles of pressure are both expensive and unconvincing. To increase the number would add an unnecessary burden on the manufacturer, yet still remain unconvincing as regards the particular vessel. The expectation that such a test will cause failure after an unknown number of pulsations, carries with it the admission that such a test may leave the vessel in a dangerous condition. Certainly a great number of pressure applications leaves a more indefinite status regarding reserve strength, than does one application of high hydrostatic pressure. Undoubtedly, fatigue testing has a proper place in the investigation of welded seams. Its usefulness coincides with that of destructive tests performed on sample drums. It is not suitable or desirable as an acceptance test to be used in production work.

One application for fatigue testing is in the investigation of the effect of high test pressures on welded seams. In line with this the second fatigue test was made on No. 2 test drum. The number of cycles was not sufficient to draw any final quantitative conclusions along this line. But it does prove that stresses far beyond the elastic limit, in fact almost to the ultimate limit, were not sufficiently injurious to this drum as to cause failure by fatigue more so [illegible] than that imposed on a boiler in its life-time. The long established custom of cold bending of boiler plate has not proven seriously injurious to the material. Surely this operation has more effect on the grain structure of the material than a hydrostatic test within the elastic limit of the material. Further experimentation along this line will be interesting.

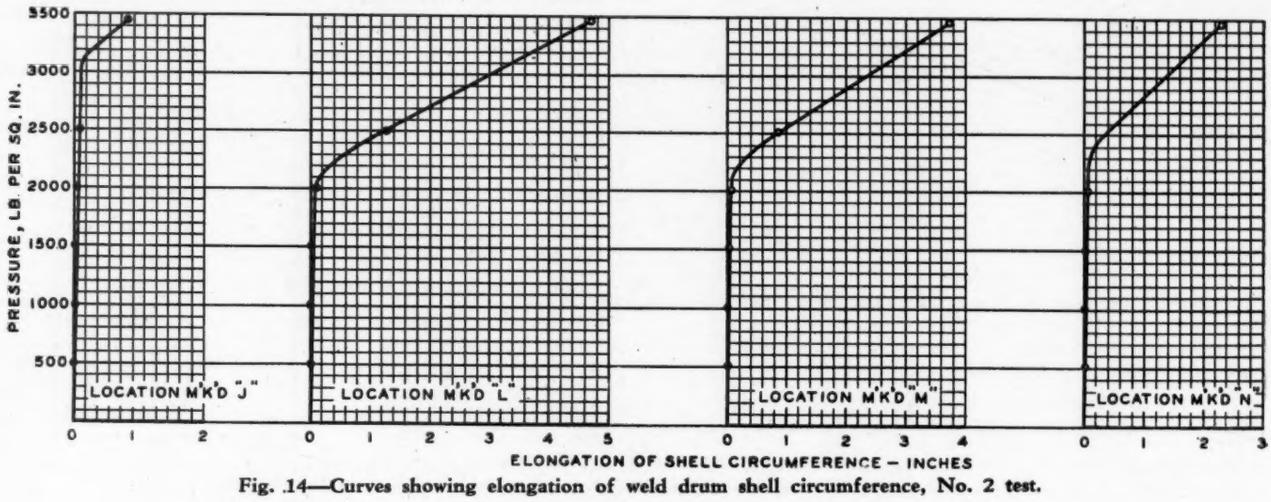


Fig. 14—Curves showing elongation of weld drum shell circumference, No. 2 test.

(4). In order to withstand such high test pressures, vessels must be designed for uniform strength throughout. That this can be obtained without exceeding practical head thickness limits, is proven by the behavior of the reinforced man-hole head in No. 2 test. Unfortunately, due to excessive width of the welding "V", the reinforcement on this head was considerably more than the design intended. Therefore further tests will be necessary to determine the minimum requirements at this point. In the same connection a liberal design was used in the reinforcement of nozzle opening. On future tests, strain gage measurements will be taken around such openings to obtain a thorough check on this design. Lastly, in order to obtain uniform stressing, fabricating methods must attain strict adherence to design in material, in dimensions and in shapes.

A Standardized Steam Generating Unit

Standardization of the design of steam generating units would admittedly be of great practical value. Such an end has been difficult of attainment heretofore because operating conditions, with respect to capacity, pressure, fuel, etc., have varied so greatly in different plants. While these obstacles still exist, developments of recent years have made them less formidable. For instance, the adoption of pulverized fuel firing has greatly widened the fuel market for plants so equipped, and furnaces designed for pulverized fuel have been found to be equally well adapted to the burning of gas or oil. Then there has been the trend toward larger units, which has facilitated standardization with respect to capacities. There is no question but that we are on the threshold of at least a measure of standardization of steam generating units, especially for larger stations, and neither is there any question as to the advantages of such a trend. Greater simplicity and compactness of units—simpler and more dependable operation—and, most important of all, greater efficiency and economy—are all results which are bound to eventuate from the sound development of the principle of standardization. In the accompanying article, the author describes a standardized type of steam generating unit which is now available in a range of sizes providing capacities from 150,000 to 400,000 lb. of steam per hour. A number of these units have already been sold and the particular one described and illustrated in this article is now being installed in an important industrial plant.

By W. J. VOGEL

Combustion Engineering Corporation, New York

GREATER efforts are constantly being made to improve efficiency and economy in the utilization of heat, and impressive progress along these lines has been made within the past several years in both central stations and industrial plants. The two factors involved are lower installation costs for building and equipment and lower operating costs. Simplicity and compactness of design in steam generating equipment are essential to minimum costs for both installation and operation. Recognition of this fact has brought about the development of the standard Combustion Steam Generator described in this article.

Five standard sizes have been designed, having capacities respectively of approximately 150,000, 200,000, 250,000, 325,000 and 400,000 lb. of steam per hr. from and at 212 deg. fahr. A number of units have at the present writing been sold abroad, and one unit is now under construction in this country for installation in a leading industrial plant. The construction of the last mentioned unit is shown in Figs. 1, 2, 3 and 4.

Referring to Fig. 1, the unit is seen to comprise a completely water-cooled furnace with turbulent firing of pulverized coal which is introduced horizontally through burners located in the four corners near the bottom of the furnace, a superheater located above the furnace, and a convection bank of tubes in the rear of the furnace extending between an upper steam drum and a lower water drum. In the rear of the convection bank is a plate type air preheater. The advantages of this arrangement becomes apparent upon considering the development of steam generating equipment and methods of firing.

Thus, with the introduction of pulverized fuel into central stations about twelve years ago, the solid refractory walls in use at that time necessitated low combustion rates to keep maintenance costs down to a reasonable amount. Hollow walls introduced some cooling of the refractory but combustion rates were still limited. The method of firing pulverized coal with little turbulence was accepted to minimize wall erosion.

In order, therefore, to reduce furnace wall maintenance and at the same time bring about lower furnace temperatures for the prevention of slag formation on the boiler tubes, a water screen was installed across the bottom of the furnace immediately above the ash pit. In addition to achieving the above results, the installation of the water screen shielded the ash from direct radiation and cooled the ash as it fell to the ash pit. The screen tubes at the furnace bottom afforded excellent heat absorbing surface. These tubes were connected to headers, located outside the front and rear furnace walls, which in turn connected to the boiler circulation. The next logical step toward the increase of furnace absorbing surface was the installation of water-cooling surface on the rear wall. The rear wall surface was made a continuation of the circulation from the bottom tubes. This combination proved so satisfactory that additional water-cooling surface was placed on the side walls. This led to furnaces provided with heat absorbing surface across the ash pit and fully water-cooled surface on the rear and side walls with air-cooled refractory walls at the front.

During the development of water-cooled furnaces, the art of burning pulverized fuel with increased turbulence and consequent higher combustion rates also advanced. Increased turbulence caused erosion

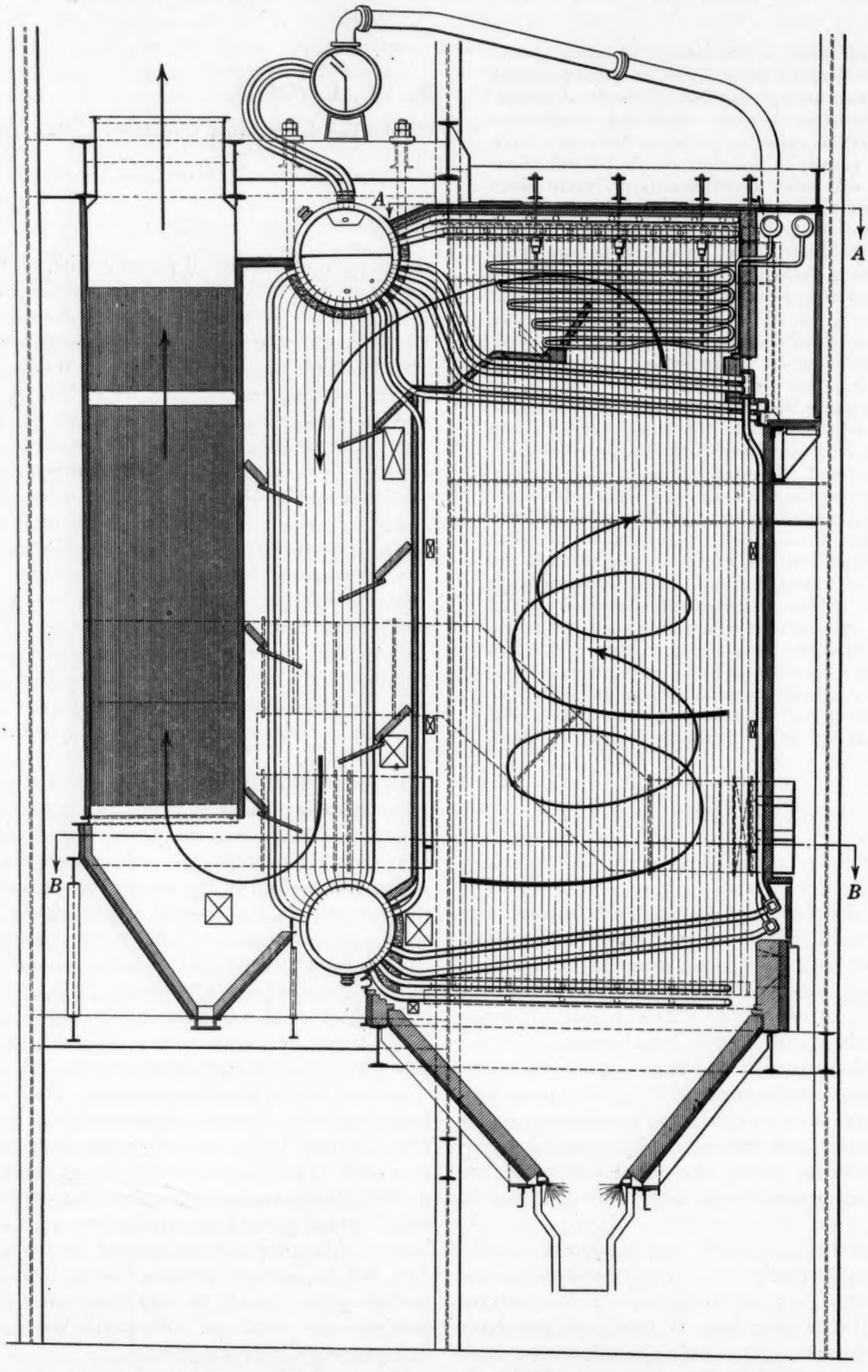


Fig. 1—Sectional elevation of standard steam generating unit designed to produce 150,000 lb. of steam per hr. at 750 lb. pressure and 750 deg. fahr. temperature.

of the front refractory walls. This led to the use of water-cooled surface on the front wall, and thus the complete water-cooled furnace evolved. This development was of major importance. It permitted increased turbulence, higher CO_2 and higher rates of heat liberation. Furnace maintenance was practically eliminated, losses due to unburned carbon were reduced and air infiltration to the furnace lessened. The net result of these improvements was a pronounced gain in the economy of steam plant operation.

The disadvantages of this development were, first, that the installation of water walls in connection with various types and sizes of boilers resulted in practically no two installations being alike, and second, that difficulties were sometimes encountered in working out an arrangement of the external circulators that would not be ungainly and excessive in space requirements.

In the unit described in this article, all the advantages of the water-cooled furnace and turbulent firing of pulverized fuel are fully realized and the minor disadvantages mentioned above are obviated. The design embodies compactness and simplicity. A building 55 ft. deep, 40 ft. wide and 85 ft. from basement level to roof line can completely house this unit, including coal storage capacity, pulverizing equipment, fan equipment and ash disposal system, and at the same time provide ample passage with 8 ft. wide aisles on both sides.

The furnace, completely water-cooled and exposing at the corners a minimum amount of refractory, is located immediately forward of the boiler convection surface. The air preheater, with no loss of intervening space, is directly behind the convection surface. The location of the air preheater permits short duct work between heater and burners, resulting in low pressure losses which in turn permit lower fan pressure. At the plant where this unit is to be installed, existing building limitations are such that the duct between heater and burners must be located outside the building columns. For future installations of this design, it is intended to arrange the column centers a few feet farther apart so that the ducts and fuel lines from mills to burners can be located within column center lines. Thus, free aisle space will be attained. It is also possible to use short straight air and gas ducts by placing the forced and induced fans immediately above the air preheater with consequent power saving.

The four furnace walls are constructed of 3½ in. O.D. tubes placed on 4 in. centers. Two headers at the top and two at the bottom of the front wall and each side wall permits close spacing of these wall tubes. Each tube end at the header is provided with its handhole plate directly opposite, resulting in straight tube rolling throughout. As shown in Figs. 1 and 2, the side walls of the furnace are supplied by tubes which fan out from the lower drum across the furnace bottom, under the water screen tubes, and connect to the lower side headers. In addition to supplying water to the side walls, these tubes provide extra cooling surface in the ash hopper. The upper side wall headers are connected to the steam drum by the roof tubes which form the support for the roof refractory. The areas of both feeder and relieving tubes are liberal and are so proportioned as to provide a very free circulation of water through the side water walls.

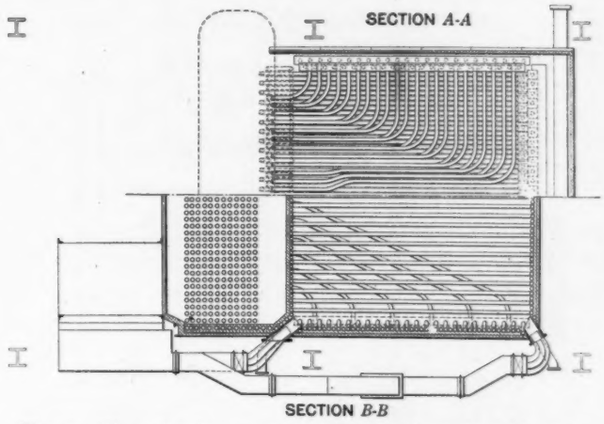


Fig. 2—View showing two horizontal sections through unit, section A-A at the top of the furnace, and section B-B at burner level.

The lower headers of the front wall are connected to the lower drum by the floor screen tubes. The top ends of the front wall tubes connect into short vertical headers, from each of which two convection tubes return the circulation to the steam drum. These tubes provide ample area so that the proportion of steam formed in them will be lower than that found in the usual similar combination of boiler and furnace water walls. The rear furnace water wall tubes connect direct to the upper and lower drums.

The main bank of convection tubes of 3 in. O.D. are arranged in parallel rows equally spaced across the setting. This close spacing will effect a worth while gain in heat transfer. Baffles are placed down the tube lengths to cause a sinuous travel of the gases.

The steam and water drum, extending beyond the setting side walls, as shown in Fig. 3, is made sufficiently large for the liberation of the steam requirements of the unit. Steam is taken from each end of the drum where there is practically no turbulence and discharged through circulation tubes to the dry drum at low velocities. A standard type of dry pipe in the dry drum connects to the outlet nozzle. Drains of large area return the condensate in the dry drum to the lower drum. These drain tubes are located within the boiler casing and are protected by refractory from the gas flow. Soot blowers are advantageously arranged throughout the unit to keep the heating surface clean.

The superheater space is of large volume and provides for access around the elements and supports and for easy removal of elements. The superheater is thus shaded from furnace radiation by the four arch tubes

and at the same time is swept by high temperature gases resulting in high superheats. To overcome the difficulties sometime experienced, especially when water-cooled furnaces are used, of obtaining the superheat desired in approximately constant degree, a by-pass damper is installed in the horizontal baffle at the uppermost arch tubes.

The convection bank of tubes and the front and side water walls are all suspended from steel framing.

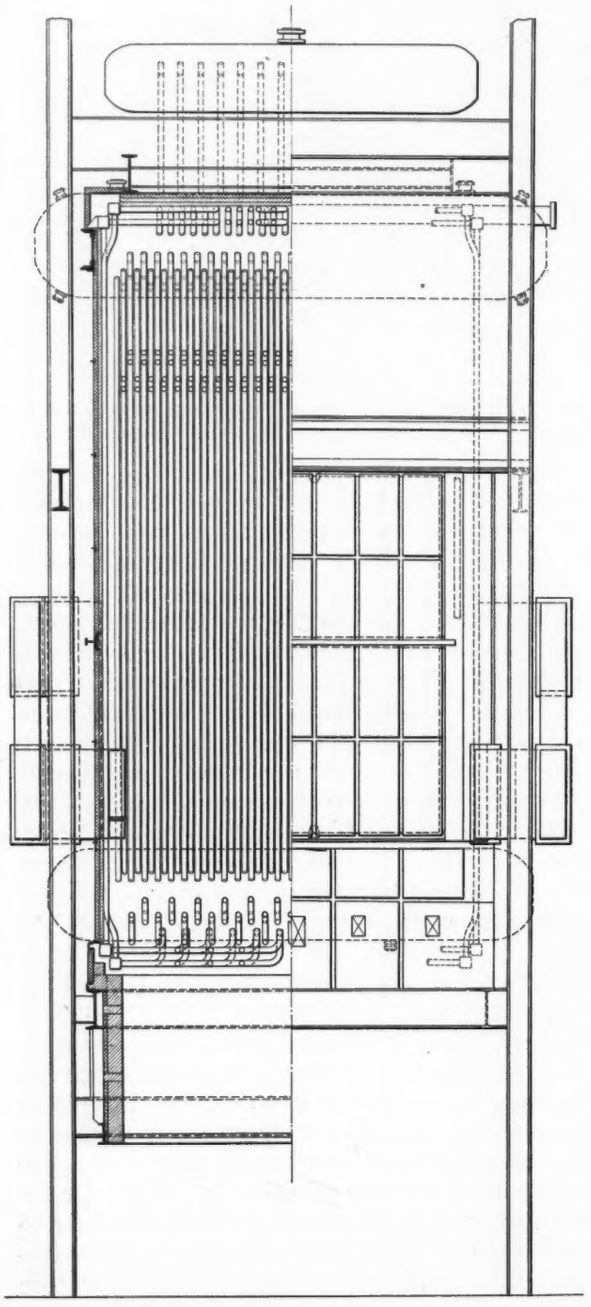


Fig. 3—Sectional front elevation.

This type of suspension permits complete freedom for expansion.

The three furnace walls and the end walls of the main convection bank are protected outside the wall insulation by a paneling of flat plates secured to a frame work of tee irons, all of which is suspended from steel above. Each panel plate, properly gasketed, is held in place with wedges which allow for easy and rapid installation or removal of panels. Each casing is provided with a horizontal band of heavy steel midway of its length to which every wall tube is flexibly connected. By this means the wall tubes are held in line. At other suitable places, the main framing members of the casings are tied back to the tubes.

This type of wall construction, combined with the general compactness of design, reduces air infiltration throughout the unit to a minimum and aids in maintaining a uniformly high CO_2.

The air preheater, comprising plate elements, is of the twin type construction and is entirely suspended from overhead steel. The elements are arranged in two sections, the bottom elements being twenty feet long and the upper elements five feet. Straight gas flow permits of ready lancing, if the condition war-

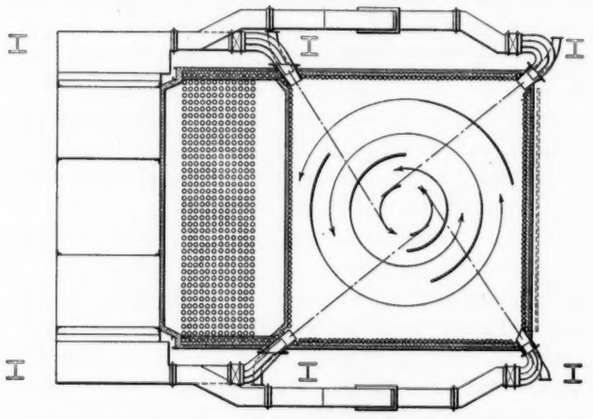


Fig. 4—Horizontal section at burner level showing tangential firing.

rants, through suitably located lancing ports. The air duct from the forced draft fan discharges into a plenum chamber located between the heaters at the level of the top section. Air flow is cross flow or horizontal through the upper elements and is directed through external connecting windboxes to the top of the lower element section. Air through this section is counterflow, discharging from the side at the bottom into the duct connecting to the burners.

Through the gradual development of pulverized fuel firing, the tangential method has been found to be the most successful. It offers the most violent turbulence with a consequent rapid rate of combustion. Also manifest over other types of firing has been the great reduction of unburned carbon in the ash pit and flue dust. As shown in Fig. 4, the burners are located at the four corners of the furnace immediately above the water screen tubes with each burner directed tangentially to an imaginary circle in the center of the furnace. There are two burners in each corner. The two coal nozzles are so arranged

(*Continued on page 55*)

Heat Engines and the Second Law of Thermodynamics*

Since the development of the first heat engines in the seventeenth century, scientists and engineers have attempted to discover and express the laws governing the production of mechanical power from heat. The science of thermodynamics was gradually evolved until it assumed the vitally important place it occupies today as a major branch of engineering knowledge. It was not until the early part of the nineteenth century that any conception was had of the phenomena involved in what is now known as the second law of thermodynamics, and a definite expression of this law was not given until the middle of that century. This law in all its ramifications is still one of the stumbling blocks to both students and practicing engineers. In the present article, Mr. De Baufre provides the background for a better understanding of this law by tracing the developments that led up to its formulation. The application of the law as we understand it today will be discussed in the next article.

•

By WM. L. DE BAUFRE
International Combustion Engineering Corporation
NEW YORK

THE first law of thermodynamics is a simple statement of the equivalence of heat and mechanical energy, and the mathematical expression representing it is directly applicable in engineering calculations. The second law, however, is concerned with more complicated phenomena, and most of the various statements which have been proposed to express it are not susceptible of mathematical formulation. For this reason, undoubtedly, power plants are often analyzed in accordance with the first law, but the second law is applied in a limited way only to steam engines and turbines by means of certain mathematical formulas used by engineers probably without a clear conception of their basis in the second law of thermodynamics.

The fundamental ideas involved in the second law of thermodynamics were conceived by an engineer, Sadi Carnot, about one hundred years ago from a study of the steam engine which, as stated at that time by Carnot, "Already works our mines, impels our ships, excavates our ports and rivers, forges iron, fashions wood, grinds grains, spins and weaves our cloths, transports the heaviest burdens, etc." It is believed that no better approach to a clear understanding of the second law in its various ramifications can be obtained, particularly for engineers, than through a study of the early history of the steam engine and of Carnot's reflections on the motive power of heat which led to the founding of the science of thermodynamics about the middle of the 19th century after the equivalence of heat and mechanical energy had been experimentally established by Joule.

*All rights reserved by the author

Early Steam Engines

It was not until the end of the 17th century that the production of mechanical work from heat became an important factor in the progress of civilization. Savery's steam pumping engine was invented in 1698 to pump water from the coal mines of England, many of which had become inoperative by reason of the expense of pumping by horse power. It is said that as many as 500 horses were so employed at a single mine. In Savery's device, Fig. 1, water was alternately forced out of and "sucked" into a vessel by the admission of steam from a boiler and the condensation of this steam by cold water sprayed over the vessel. The steam pressure was determined by the height necessary to raise the water.

Failure of the crude boilers which could then be constructed, quickly led to the invention in 1705 of the Newcomen pumping engine using steam at atmospheric pressure only. In order to accomplish this, the water pump was separated from the steam cylinder and operated through an oscillating beam by a piston moving vertically in a steam cylinder as shown in Fig. 2. The admission of steam at atmospheric pressure to the cylinder permitted the piston to rise by reason of the weight of the reciprocating parts of the pump and a counterpoise hung on the oscillating beam. Condensation of the steam within the cylinder by a jet of cold water then created a vacuum so that the piston was forced down by the pressure of the atmosphere. By 1725, the Newcomen engine was in common use in collieries in England and held its place without material change for over half a century later. In 1764, Watt, an instrument maker in the University of Glasgow, proposed the improvement of adding a condenser separate from the steam cylinder in order that the latter could be kept warm and thus reduce the large loss of steam by condensation which occurred in the Newcomen

engine when steam entered the cylinder cooled by the water used to condense steam previously admitted.

The maximum amount of work these early steam engines were capable of performing evidently equaled the external latent heat of the steam generated in the boiler. Due to initial condensation of steam as it entered the cylinder and to other imperfections, the actual amount of work done in any particular case was much less. In 1769, Watt conceived the idea of using steam expansively, that is, of cutting off its admission to the cylinder before the end of the stroke of the piston, thereby obtaining additional work from the steam during its expansion. This idea, however, was not practically applied until many years later when improvements in methods of construction enabled boilers to be built which could be operated safely at pressures several times that of the atmosphere.

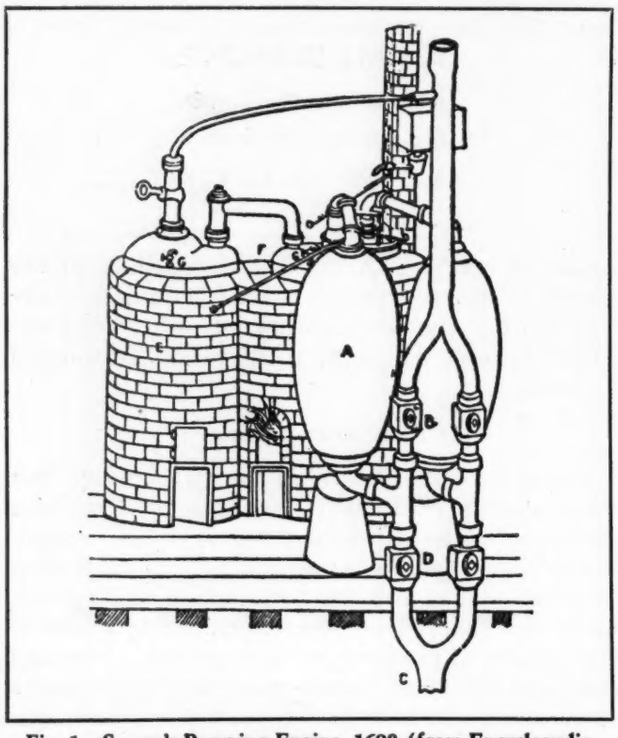


Fig. 1—Savery's Pumping Engine, 1698 (from Encyclopedia Britannica).

Watt also invented the "indicator" to study the action of steam in engine cylinders. The expansion curve for steam was found to approximate a rectangular hyperbola with the product of the pressure and volume equal to a constant quantity. Such a curve was also supposed at that time to represent the relation between the pressure and the volume of steam in the saturated condition. From some rough experiments on the heat given up by condensing steam, Watt concluded that the total heat of saturated steam was the same at all pressures. The heat removed by condensing steam in the condenser of a steam engine was therefore believed to be equal to the heat required to generate the same amount of steam in the boiler, in conformity with the conception of heat as an imponderable fluid not to be created nor destroyed.

Carnot's Reflections

In 1824, Sadi Carnot, a young French civil engineer, published his reflections on the motive power of heat. Carnot conceived the production of mechanical work by heat to be due to the caloric fluid experiencing a drop in temperature analogous to the production of work by a weight in falling through a vertical distance. In the steam engine, the work performed by the piston is evidently due to the alternate expansion of water into steam and the contraction from steam to water again by the addition and abstraction of heat during its passage from the high temperature of the boiler to the lower temperature of the condenser. Since all substances are capable of doing work by expanding and contracting through the alternation of heat and cold, Carnot argued that any substance could be employed as a working medium in a heat engine. He also argued that wherever a difference in temperature exists, it should be possible to produce mechanical work by some working medium utilizing the fall of caloric from the higher to the lower temperature.

Carnot raised the question as to whether the motive power produced by the passage of heat between any two given temperatures would vary with the working medium employed and whether any other substance would be a more efficient working medium than steam. He obtained an answer by considering two heat engines with different working fluids, one of which engines was assumed to drive the other backwards. The one heat engine was supposed to take in a quantity of heat at the higher temperature, produce mechanical work and then discharge the same quantity of heat at the lower temperature. The reversed heat engine was supposed to consume mechanical work in raising a quantity of heat from the lower to the higher temperature.

Each of these two heat engines was assumed to operate without frictional resistances and without any direct transfers of heat between substances at different temperatures. While temperature differences are necessary in an actual heat engine to transfer heat from the "source of heat" to the working medium and to reject heat from the working medium to the "source of cold", such temperature differences may be made very small and were taken as zero by Carnot for the sake of argument. Changes in temperature of the working medium between the temperature at which heat was taken in and the temperature at which heat was rejected, were assumed to result from adiabatic expansion or compression of the working medium. Under the further assumption that the working medium passes through a complete cycle of events so that the heat in the working medium at the end of the operation is the same as at the beginning, the reversed heat engine must raise

from the lower to the higher temperature with consumption of a given quantity of mechanical work, the same quantity of heat as would pass from the higher to the lower temperature in producing an equal quantity of mechanical work by this engine, that is, the engine is "reversible."

The above assumptions eliminated all differences between the two heat engines relative to the passage of heat and the production of work except those due to different properties of the working mediums, such as specific heats, coefficients of expansion, etc. Hence, if the working medium in the driving engine were inherently more efficient than the working medium in the driven engine, an excess of mechanical work could be produced without any net transfer of heat between the "source of heat" and the "source of cold." Such a creation of motive power without transfer of heat or any other cause to account for it, was considered inadmissible by Carnot based on the then g nerally accepted idea that "perpetual motion" is impossible. He therefore concluded that the maximum motive power theoretically possible with steam is also the maximum possible with any other substance as a working medium and depends only upon the upper and lower temperatures and the quantity of heat transferred.

In order to demonstrate the correctness of these conclusions and determine the numerical relation of the maximum possible motive power to the heat transferred and the temperature range, Carnot made calculations for air, steam and alcohol, assuming each of these mediums to pass through a complete reversible cycle of expansions and compressions. He found that approximately equal quantities of mechanical work were performed by the several working mediums for the passage of equal quantities of heat through the same small temperature range at the same point in the temperature scale.

Carnot's reflections on the motive power of heat introduced into the study of heat engines, the fundamental ideas of the reversibility or irreversibility of physical processes, of complete and incomplete cycles of events and of a definite relation between the quantity of heat taken in by a heat engine operating in a complete cycle through a given temperature range and the maximum possible amount of mechanical work produced, irrespective of the working medium employed in the engine. His proof of the last mentioned relation lost its validity, however, when the experimental work of Joule in the 1840's demonstrated the equivalence of heat and mechanical work as different forms of energy. It therefore became necessary to find a new principle upon which to base the proof or to discard the idea of the efficiency of a reversible heat engine operating in a complete cycle having a definite value corresponding to the temperatures of the source of heat and the source of cold and independent of the working medium employed in the engine. Such a new principle was enunciated in 1850 by Clausius, a German physicist, and designated by him as the second general principle of the mechanical theory of heat, the first general principle being that of the equivalence of heat and mechanical work as different forms of energy.

The Perfect Heat Engine

Before giving Clausius' statement of his second general principle of the mechanical theory of heat, now known as the second law of thermodynamics, we will examine the complete cycle of the reversible heat engine as first proposed by Carnot but as modified by Clausius in accordance with his mechanical theory of heat. In accordance with this theory, the heat discharged at the lower temperature by such a perfect heat engine is less than the heat taken in at the upper temperature by an amount equivalent to the mechanical work done. When the operation of the engine is reversed, the heat discharged at the higher temperature is greater by the mechanical work consumed than the heat taken in at the lower temperature.

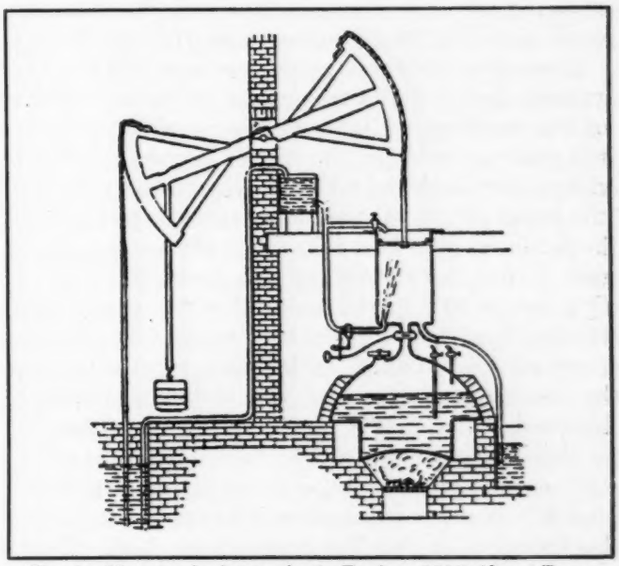


Fig. 2—Necomen's Atmospheric Engine, 1705 (from Encyclopedia Britannica).

The complete cycle of Carnot's perfect heat engine comprises four steps, as follows:

(A) Isothermal expansion of the working medium, absorbing Q_1 units of heat at the absolute temperature T_1 from the "source of heat";

(B) Adiabatic expansion of the working medium from the temperature T_1 to the lower temperature T_2;

(C) Isothermal compression of the working medium, rejecting Q_2 units of heat at the absolute temperature T_2 to the "source of cold"; and

(D) Adiabatic compression of the working medium from the temperature T_2 to its original condition at temperature T_1.

To illustrate the work performed during such a complete cycle of events, the Watt "indicator diagram" will be utilized as was first done in 1834 by Clapeyron, a French mining engineer. Thus, in

Fig. 3, the curve 1 2 represents isothermal expansion of the working medium while the quantity of heat Q_1 is being taken in from the source of heat at absolute temperature T_1, the external work performed being indicated by the area 1 2 V_2 V_1 under this curve. During adiabatic expansion from 2 to 3 while the temperature drops from T_1 to T_2, the external work done by the working medium is indicated by the area 2 3 V_3 V_2. During isothermal compression from 3 to 4, the quantity of heat Q_2 is rejected to the source of cold at absolute temperature T_2 and the work 3 4 V_4 V_3 is done upon the working medium. The point 4 must be so chosen that by adiabatic compression from T_2 to T_1, the working medium is brought back to its initial condition at point 1, the work 4 1 V_1 V_4 being done upon the working medium. The net work W performed during the complete cycle is evidently equal to the area 1 2 3 4 inclosed by the two isothermals and the two adiabatics; and, in accordance with the first law of thermodynamics, A W = $Q_1 - Q_2$. The thermal efficiency of such an engine has been defined as the work done divided by the heat taken in, or A W / Q_1.

If one of such heat engines were more efficient than another due to differences in the inherent properties of the working mediums employed, then by having the first engine drive the second engine backwards, either heat could be made to flow continually from the lower to the higher temperature or power could be produced from heat taken in at the lower temperature. Thus, for the first engine, let A W′ = $Q'_1 - Q'_2$, where Q'_1 is the heat taken in at the upper temperature T_1, Q'_2 is the heat rejected at the lower temperature T_2 and W′ is the mechanical work done by the engine. For the second engine operating backwards, let A W″ = $Q''_1 - Q''_2$, where Q''_2 is the heat taken in at the lower temperature T_2, Q''_1 is the heat rejected at the upper temperature T_1 and W″ is the mechanical work required to drive it backwards. If the first engine were more efficient than the second engine and W′ = W″, then Q''_1 would be greater than Q'_1 and Q''_2 would be greater than Q'_2 by the same amount of heat, which would be transferred from T_2 to T_1. On the other hand, if $Q'_1 = Q''_1$, then W′ would be greater than W″ and the difference W′ — W″ would be equivalent to $Q''_2 - Q'_2$, the excess heat taken in at T_2.

In neither case is there "perpetual motion" as understood in Carnot's time; consequently, Carnot's reasoning based on the impossibility of "perpetual motion" does not hold good for concluding that the efficiencies of the two engines must be equal. Yet neither of the two results of assuming the efficiencies unequal appears to be reasonable. The second result, namely, the obtaining of mechanical work by conversion of heat from a temperature equal to or below that of the surroundings, has been called perpetual motion of the second class in contradistinction to obtaining work from nothing, designated as perpetual motion of the first class.

Apparently from consideration of the first unreasonable result, Clausius propounded in 1850 as a second fundamental principle of the mechanical theory of heat that "heat cannot of itself, or without

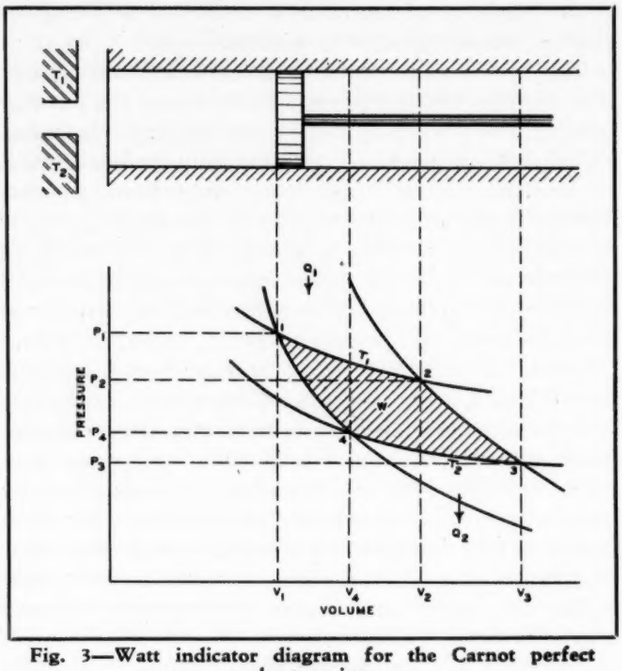


Fig. 3—Watt indicator diagram for the Carnot perfect heat engine

compensation, pass from a colder to a hotter body" Apparently from consideration of the second unreasonable result, Lord Kelvin in 1851 proposed the axiom, "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest surrounding objects." These two statements have since become known as alternate statements of the second law of thermodynamics.

Rankine claimed to have discovered the second law of thermodynamics independently of Clausius and his statement of the law is still occasionally quoted, namely, "If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any number of equal parts, the effects of those parts in causing work to be performed are equal." This statement was supplemented by Rankine with two other statements; but none of his statements are to be preferred over those of Clausius and Lord Kelvin.

Other statements for the second law of thermodynamics have since been proposed by various authors, several of which statements will be discussed in the article to follow on available energy and entropy. Any such statement should either serve as a foundation stone for this branch of the subject or as a working tool for applying the subject to practical problems.

Efficiency of the Perfect Heat Engine

The second fundamental principle of Clausius is the most often quoted statement of the second law of

thermodynamics. It is not susceptible of mathematical formulation and is therefore not of direct use in engineering calculations. Its acceptance as a fundamental truth, however, leads to the conclusion that the maximum possible efficiency is the same for all heat engines operating in a complete cycle between the same upper and lower temperatures irrespective of the working mediums employed therein. We can then proceed to derive the mathematical expression for this maximum efficiency by assuming the simplest possible properties of the working fluid, namely, those of a perfect gas.

Referring to Fig. 3, the isothermal expansion line 1 2 for a perfect gas is a rectangular hyperbola, so that $P_1 V_1 = P_2 V_2$ and the work done, $A R T_1 \log_e (V_2 / V_1)$, is equal to the quantity of heat Q_1 taken in at absolute temperature T_1. For adiabatic expansion from 2 to 3, the pressure-volume relation of a perfect gas is $P_2 V_2^k = P_3 V_3^k$ and the work done by the gas is equal to its decrease in internal energy $(P_2 V_2 - P_3 V_3) / J (k - 1)$. For isothermal compression from 3 to 4, $P_3 V_3 = P_4 V_4$ and the work done upon the gas, $A R T_2 \log_e (V_3 / V_4)$, is equal to the quantity of heat Q_2 rejected at absolute temperature T_2. For adiabatic compression from 4 to 1, $P_4 V_4^k = P_1 V_1^k$ and the work done upon the gas equals the increase in internal energy $(P_1 V_1 - P_4 V_4) / J (k - 1)$. The net work done by the gas during the complete cycle 12341 is therefore

$$A W = ART_1 \log_e \frac{V_2}{V_1} + \frac{P_2 V_2 - P_3 V_3}{J (k - 1)}$$

$$- ART_2 \log_e \frac{V_3}{V_4} - \frac{P_1 V_1 - P_4 V_4}{J (k - 1)}$$

Since $P_1 V_1 = P_2 V_2$ and $P_3 V_3 = P_4 V_4$, the work done by the gas during adiabatic expansion is equal to the work done upon the gas during adiabatic compression and these terms may be canceled. Since $P_2 V_2^k = P_3 V_3^k$ and $P_1 V_1^k = P_4 V_4^k$, it may be shown that $V_2 / V_1 = V_3 / V_4$. Therefore, the net work done reduces to

$$A W = A R (T_1 - T_2) \log_e \frac{V_2}{V_1}$$

The thermal efficiency of a Carnot perfect heat engine is therefore

$$\frac{A W}{Q_1} = \frac{T_1 - T_2}{T_1}$$

Although derived from the Carnot cycle, this mathematical expression for the thermal efficiency of a perfect heat engine must apply to any other cycle which is reversible, in accordance with Clausius' or Lord Kelvin's statement of the second law. One other reversible cycle is known, namely, that devised by Stirling in 1827, in which Carnot's adiabatic expansion and compression of the working medium are replaced by reversible transfers of heat to and from a "regenerator" with infinite heat capacity. The temperature of the working medium is reduced from T_1 to T_2 by passing through the regenerator and giving up a quantity of heat thereto. This quantity of heat is reabsorbed by the working medium after isothermal compression by passing through the regenerator in the reverse direction, the temperature being raised from T_2 to T_1.

We may therefore say that when any medium is used to convert heat into mechanical work by operating in a complete cycle between an upper absolute temperature T_1 and a lower absolute temperature T_2, the maximum possible portion of the heat supplied at T_1 which can be converted into mechanical work before rejecting the remainder at T_2, is equal to $(T_1 - T_2) / T_1$. This may be regarded as a statement of the second law of thermodynamics which is directly applicable to engineering calculations.

The above mathematical relation for the efficiency of a perfect heat engine is of limited use, however, because it can be applied only in cases where the source of heat remains at a constant absolute temperature T_1 during the withdrawal of the quantity of heat Q_1. This is true for the condensation of steam and other pure vapors under constant pressure; but most sources of heat, such as the products of combustion in furnaces, change in temperature as heat is withdrawn from them. To apply the above relation to such cases, it must be modified as will be explained in the article to follow on available energy and entropy.

It is sometimes said that heat is low grade energy in comparison with mechanical, electrical and chemical energy, and whereas one of these high grade forms of energy can be completely converted into low grade heat energy, it is impossible to convert more than a fraction of heat energy into mechanical or other high grade energy. From the discussion in a previous article of isothermal expansion of a perfect gas, it is seen that theoretically 100 per cent of the heat added can be converted into mechanical work. Practically, 100 per cent of the heat added to any real expanding gas is converted into mechanical work when the internal energy after expansion is equal to the internal energy before expansion. By utilizing, for example, the supply of natural gas from a field where the pressure may be 1000 lb. per sq. in., it would be possible to convert into mechanical work a very large portion of any heat added to the gas. It is true that the gas will be at a lower pressure after converting the heat into work than it was before doing so. But the statement, "experience shows that heat energy is not capable of complete conversion into mechanical work," should be limited to a heat engine in which the working medium passes through a complete cycle of events.

References

Carnot's "Reflections on the Motive Power of Heat and on Machines Fitted To Develop That

(*Continued on page 47*)

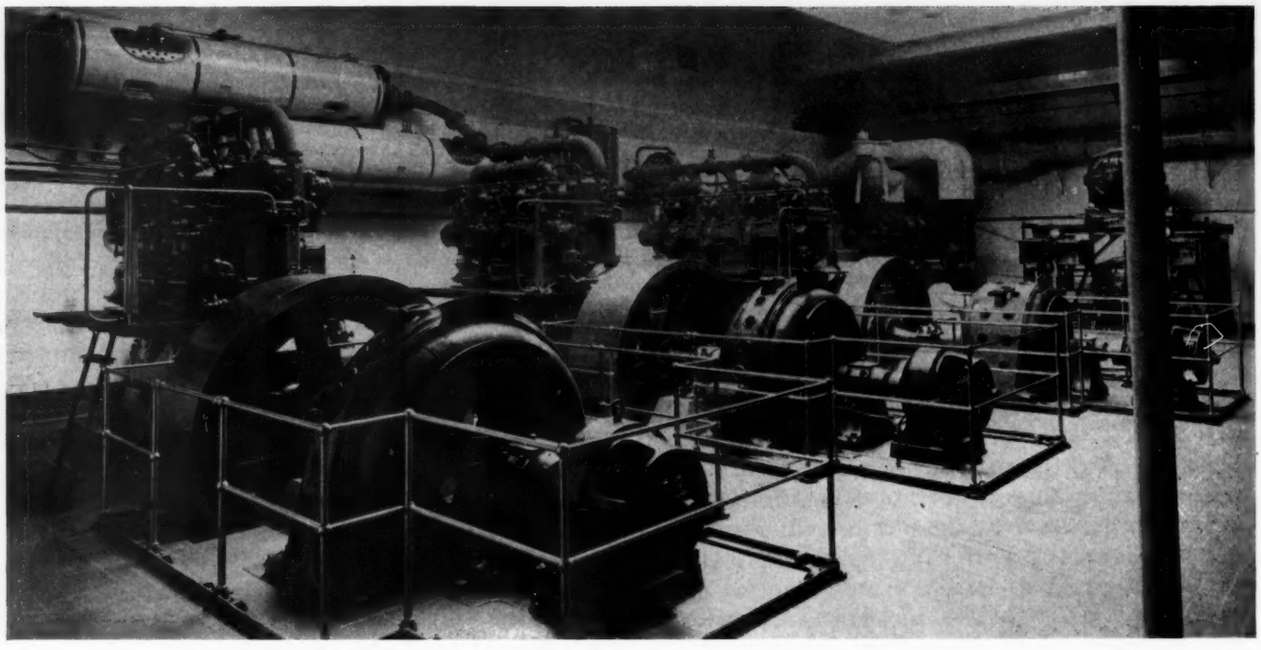


Fig. 1—Installation of two 3-cylinder Ruston 150 b.h.p. oi engines and one 4-cylinder Ruston 200 b.h.p. oil engine with exhaust heat boilers.

Exhaust Gas Boilers for Internal Combustion Engines

British Practice in a New and Important Field

By DAVID BROWNLIE
LONDON

The use of waste heat boilers operated by the exhaust of oil or gas engines is a practice which is little known in this country. Mr. Brownlie's interesting discussion of this development would indicate that substantial progress along this line is being made in Great Britain. His article describes several types of boilers which have been specially designed for this service and contains information on the economic and other advantages of such installations.

•

OBVIOUSLY, one of the next great advances in the field of combustion, and one that is already well on its way, is the utilization for steam generation of the heat in the exhaust gases of internal combustion engines, particularly Diesel and other oil engines and large gas engines, especially those utilizing blast furnace gas.

In the present contribution, an attempt will be made to give a description of the latest British practice in waste heat boilers of designs that are particularly adaptable for use with Diesel engines, as represented by the work of three prominent firms, Cochran & Company, (Annan) Ltd., Annan, Scotland, Ruston and Hornsby Ltd., Lincoln, and Spencer-Bonecourt Ltd., London.

Naturally exhaust gas boilers of this character are being largely used in marine work because of the rapidly growing use of Diesel engines for ship propulsion, and the necessity in such vessels for steam in connection with auxiliaries and for heating and hot water supply. Obviously, therefore, the ideal practice is to use waste heat boilers operated by the exhaust of the main Diesel engines, with auxiliary oil-firing, in preference to the original practice of having entirely separate boilers with oil-firing only. Such boilers also have a growing field in stationary plants since more and more use will be made of the Diesel engine in land practice, not only for taking the peak load in steam-driven power stations and as a stand-by addition to small hydro-electric stations for use when the water is low, but also in all kinds of industrial establishments.

In a country such as the United States with abundant liquid fuel, and in others more or less devoid of native fuel and consequently dependent upon imported fuel, with high cost of carriage, the Diesel

engine with exhaust gas boiler constitutes an extremely convenient and efficient arrangement for a large number of mills, factories, and workshops. The ideal conditions for the Diesel engine are of course electric driving with only relatively small heating and process steam requirements. Where the opposite conditions exist, of course, the best practice is steam boilers, generation of electricity by means of back-pressure engines or non-condensing turbines, and use of all the exhaust steam for process work, giving an overall thermal efficiency of say 50 to 65 per cent from the raw fuel to the final place of use.

In this connection, obviously one of the great advantages of the Diesel engine exhaust gas boiler is the high overall thermal efficiency of the combined set. Thus a Diesel engine in average normal running is giving results of say 35 to 40 per cent thermal efficiency with a temperature of about 500 to 750 deg. fahr. in the exhaust gases, corresponding to 25 to 40 per cent of the total heat in the original oil, depending of course on whether a 4-stroke or a 2-stroke engine is being used, and the speed of revolution and the power output. By the use of efficient waste heat boilers, supplied with hot water from the engine jacket, about 60 per cent of the total heat in the exhaust, that is equivalent to 15 to 25 per cent of the fuel oil, can be utilized for steam generation, reducing the final gases to about 350 deg. fahr. as discharged. Approximately the performance can be taken as 0.75 to 1.00 lb. of steam per b.h.p. per hr. with a normal 4-stroke Diesel engine and 0.30 to 0.50 lb. with a 2-stroke engine, while, of course, hot water can be supplied direct instead of steam.

Obviously, therefore, the overall thermal efficiency of the combined set is very high as compared with a condensing steam turbine power station averaging say 17 to 20 per cent thermal efficiency, but with as much as 27 to 28 per cent under conditions of very high steam pressures and temperatures.

Modern exhaust heat boiler practice for Diesel engines consists essentially in the use of various types of multi-tube units, horizontal or vertical, so designed as to allow of easy accessibility for cleaning and general examination, and to operate under such conditions that the final exhaust gases are not reduced below about 320 to 350 deg. fahr. so as to prevent corrosion. Further, such boilers are supplied in two general types, although with various modifications in each case. The first is an exhaust heat unit only, that is generating steam variable in output according to the condition of the Diesel engine exhaust. Second, there is the much more usual "composite" type of boiler, that is an exhaust heat unit fitted also with direct oil firing, the latter being adjusted in amount, or shut down entirely, according to the circumstances of the steam demand and the amount generated by the exhaust gases. This arrangement is essential, for example, in ship work when the steam boiler operates the steering gear, electric lighting set, or other auxiliaries, since the main Diesel engines may often be shut down, as in a fog, while some of the auxiliaries, as well as heating steam, are required when in harbor.

Exhaust gas boilers are completely equipped with the usual fittings such as pressure gage, double spring-loaded safety valve, stop valve, check feed valves gage glasses and protectors, water level indicator, shut-off valves, blow-off cock, salinometer cock, manhole and lid, inspection doors, feed pump or injector, and oil burners, and they may also be operated with economizers and even superheaters in the case of very large internal combustion engines.

The Cochran exhaust gas boilers for Diesel and other internal combustion engines are a modification of the well-known standard Cochran vertical steam boiler, as illustrated in Fig. 3. Essentially the standard arrangement of tube plates and tubes is followed but the exhaust heat boiler has, of course, no furnace and is provided in the casing with special wide-diameter exhaust gas inlet and corresponding outlet, the latter being at the bottom. The gases enter at the top and pass through a nest of horizontal tubes, then down inside the casing and out in the reverse direction through a second nest of horizontal tubes.

For the Cochran composite boiler there are generally three groups of horizontal tubes, that is an upper and lower set for the exhaust gases, as in the exhaust gas boiler, and an additional third set below for the oil burners.

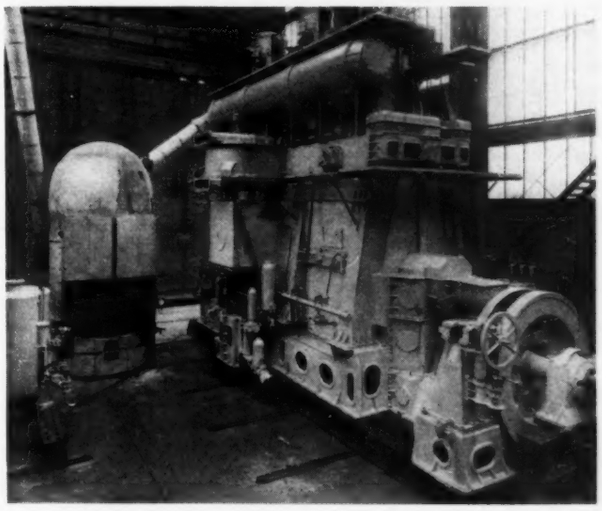


Fig. 2—Cochran composite boiler 20 ft. 6 in. high by 8 ft. 6 in. diameter, with 1890 sq. ft. heating surface, operating at 120 lb. pressure in connection with a Marine Diesel engine.

The exhaust gas and the composite boilers, exhaust gas and oil fired, are supplied in approximately the same standard sizes as Cochran standard boilers of which the smallest size is 3 ft. dia. and 8 ft. high with 60 sq. ft. of heating surface and weighing, complete with fittings, 5040 lb. The normal pressure is 100 lb. per sq. in. although units have been built for pressures up to 150 lb. and over. The largest Cochran standard boiler is an oil-fired marine unit, 8 ft. 6 in. dia. and 19 ft. 3 in. high with 1,000 sq. ft. of heating

surface, giving an evaporation of 6,000 lb. of water per hr.

A typical installation is that of a Cochran Diesel engine exhaust gas boiler, 5 ft. 6 in. dia. by 13 ft. 6 in. high, corresponding to a heating surface of 810 ft. This boiler, of the double-pass type, has 290 sq. ft. of area through each of the nests of horizontal tubes, and is suitable for operation with a 2000 b.h.p. Diesel engine of the 4-stroke type or a 1160 b.h.p. engine of the 2-stroke type. As typical of the larger exhaust gas boilers, a unit has been installed which is of the double-pass type, 8 ft. 6 in. dia. by 19 ft. 3 in. high, with a heating surface of 2240 sq. ft. and with 5750 sq. in. of area through the tubes. This unit will take the exhaust from a 3800 b.h.p. 4-stroke Diesel engine.

As regards the composite boilers for combined exhaust heat and oil burners, a typical large Cochran unit is 8 ft. 6 in. dia. and 20 ft. 6 in. high, with a heating surface of 1300 sq. ft. and 4000 sq. in. area through the tubes, double-pass type. This portion deals with the exhaust from a 4-stroke Diesel engine of 2780 b.h.p. while the oil-fired portion has an

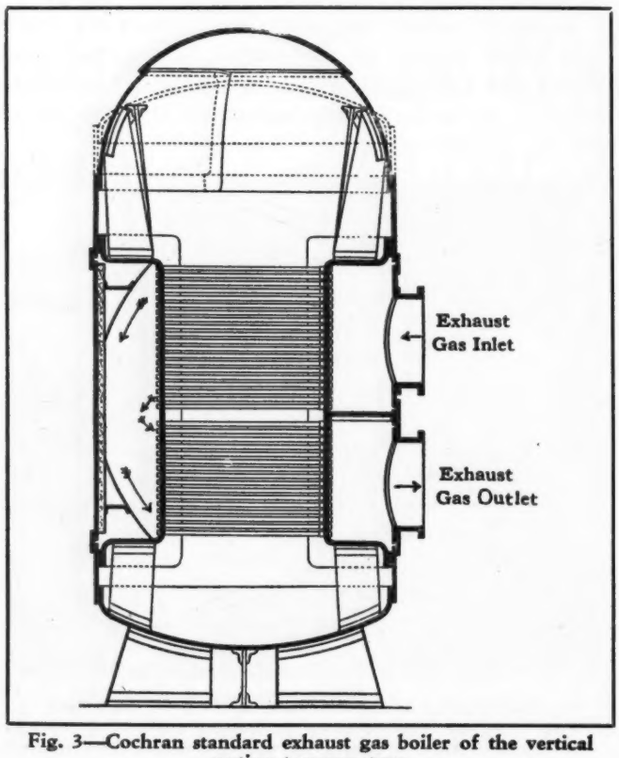


Fig. 3—Cochran standard exhaust gas boiler of the vertical section two-pass type.

evaporation of 3000 lb. of water per hr. with feedwater at 60 deg. fahr. As already indicated, the evaporation of the exhaust section corresponds approximately to 0.75 to 1.0 lb. of steam per b.h.p. hr. from an average 4-stroke Diesel engine, and 0.3 to 0.5 lb. per b.h.p. hr. from a 2-stroke unit.

As another example there may be mentioned a Cochran composite boiler installed on the vessel Sheaf Holm, which is 8 ft. 6 in. dia. by 20 ft. 6 in. high, having 1890 sq. ft. of heating surface, and operating at 120 lb. per sq. in. working pressure in conjunction with a Doxford Diesel engine set constructed by Doxford & Sons Ltd. of Sunderland. This boiler is of the 2-pass type and the temperature of the exhaust gases at 700 deg. fahr. from the engine is reduced to 300 to 400 deg. fahr. before discharge to the air, while very accurate tests carried out in the shops showed that an evaporation of 0.84 lb. per b.h.p. hr. is obtained with feedwater at 60 deg. fahr. with the engine developing 2000 b.h.p., corresponding approximately to 1 lb. water from and at 212 deg. fahr. evaporated per b.h.p. This installation is running with great success under sea-going conditions.

It may be mentioned further that generally the composite boiler has 1½ in. external diameter tubes for the exhaust gas portion and 2 to 2½ in. tubes for the oil-fired section with two or three passes. With a 4-stroke engine, the 2-pass arrangement is used for the exhaust of a composite boiler but in some cases, a I-pass is sufficient for a 2-stroke engine because of the low temperature of the exhaust.

The Ruston exhaust boiler for Diesel and for oil engines is generally of the horizontal multiple tube type, varied in minor points of design according to the type of engine used. Thus, for oil engines, the connecting inlet and outlet chambers are of the same diameter as the boiler itself, but in the case of gas engines the connection to the boiler as well as the exhaust is of the steel coned type, and in this case there may be included when desired a special explosion valve, although this is not generally necessary.

Ruston & Hornsby Ltd. make a very wide range of oil and gas engines of all types, and naturally the exhaust heat boiler is supplied according to the circumstances. For example, they state that, with their standard cold-starting oil engine, there is not so much heat in the exhaust as in gas engines, while further, if the average load of an oil engine is not about 75 per cent of the total capacity then it is better to use an exhaust heater for hot water supply instead of steam. In such a case, a typical smaller size of oil engine of 100 b.h.p. running at 75 per cent load will heat 1000 lb. of jacket water per hr. at 100 deg. fahr. up to 200 deg. fahr., a valuable point in connection with many industries using hot water, and also in connection with the operation of large buildings such as hotels, department stores, apartments and sanatoriums.

A number of well-known large buildings in London are operating on Ruston oil engines and exhaust heat boilers, of which a typical example is Bentalls Drapery and Furnishing Store at Kingston-on-Thames, with an installation of two 3-cylinder Ruston 150 b.h.p. oil engines and one 4-cylinder Ruston engine of 200 b.h.p., including the necessary equipment of exhaust heat boilers.

Also the firm supply a composite boiler available both for gas and oil firing, and for use in conjunction with all types of internal combustion engines. In this connection, their experience is that in the case

of a gas engine running under normal conditions of 75 to 100 per cent load with a consumption of 10,000 B.t.u per b.h.p. per hr., if the exhaust heat boiler is placed very close to the engine, about 32 per cent of the heat, or 3200 B.t.u. per b.h.p. per hr., is available at the inlet end of the boiler, which operates at about 60 per cent thermal efficiency and, of course, with any desired pressure. Thus, for example, a medium sized gas engine of 500 b.h.p. running 70 hr. a week will give an amount of steam in exhaust gas boilers equal to the saving of about 220 tons of coal per annum, quite apart from the additional economy

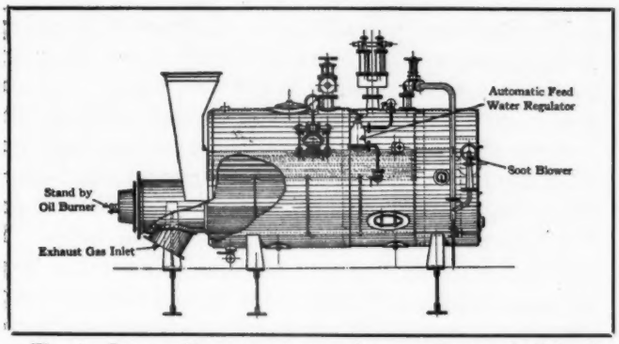


Fig. 4—Spencer-Bonecourt composite waste heat and oil fired boiler for Diesel engines.

in labor and attendance in connection with the latter amount of coal.

Another feature of Ruston waste heat boiler practice in conjunction with internal combustion engines is the use of a special patented cast iron feedwater economizer as an auxiliary. In this way the temperature of the feedwater can be raised by about 100 deg. fahr. giving a further economy equivalent to about 8 per cent of the total heat in the original oil, when using the Diesel engine jacket water in the ordinary way. With this unit, because of the cast-iron construction, there is no trouble with corrosion when the temperature of the final gases is reduced below 350 deg. fahr.

The Spencer-Bonecourt waste heat boiler for use in connection with the utilization of the exhaust of Diesel engines, gas engines, and other internal combustion engines, is also of the multi-tube type, arranged either vertically or horizontally, and so designed as to allow of special cleaning facilities for both the hot gas and the water sides of the heating surface. The latter is claimed to be so large that the temperature of the gases leaving the boiler for final discharge is only about 120 deg. fahr. higher than the steam temperature, giving also less back pressure on the engine than in the case of the ordinary muffler.

In order to meet all the different requirements, especially in conjunction with Diesel engines, Spencer-Bonecourt exhaust gas boilers are made in five separate classes. The "W" boiler has cored tubes, being either of the vertical or horizontal type, and particularly intended for small gas engines and Diesel engines, while the class "D" boiler, of the vertical type only, has small diameter tubes operated at high gas flow velocity, and being the standard design for Diesel engines, especially marine work, when auxiliary oil firing is not necessary.

Next there is the class "K" boiler with larger tubes than those in the "D" class, on the horizontal principle, intended for slow-running engines such as large blast furnace gas engines. The "G.J." class is another modification of the "D" class but equipped with water-tube screen and firebox so as to allow of auxiliary oil firing, being the standard composite type for marine Diesel engines when it is necessary to have oil firing additional or as an alternative. Finally there is the "R" class, which is also a combined waste heat return tube boiler with alternative oil firing, intended for special cases, particularly on board ship, when the "G.J." standard class is not adaptable to the lay-out.

As a result of their extensive experience, Spencer Bonecourt Co. Ltd. has prepared some very interesting charts relating to the steam production of these waste heat boilers as applied to Diesel engines and to gas engines, the calculations being based in the latter case on an average consumption of 9000 B.t.u. per b.h.p. per hr. with producer or blast furnace gas, while the corresponding Diesel engine figure is a fuel consumption of 8500 B.t.u. per b.h.p. per hr. For the purpose of this calculation, the steam is taken as 100 lb. per sq. in., that is a saturation temperature of 338 deg. fahr.

Thus a typical combination with the 4-stroke Diesel engine is 750 deg. fahr. in the exhaust with 100 to 125 per cent excess air, while the 2-stroke Diesel engine is 550 deg. fahr. with 150 to 200 per cent excess air, although with control scavenging the practice approaches the 4-stroke type. With gas engines, the exhaust normally varies from 750 to 840 deg. fahr. in the case of 150 to 200 per cent excess air. For example, from these curves it is shown that with Diesel engines between the variations of 500 to 800 deg. fahr. in the exhaust temperature, and 100 to 200 per cent excess air, the amount of steam evaporated from and at 212 deg. fahr. per b.h.p. per hr. varies from 0.50 to 2.00 lb. per hr. The figure, of course, increases as the temperature of the exhaust from the engine increases, and also as the percentage of excess air rises. Further, in this connection, it is pointed out that the exhaust gas temperature from Diesel engines falls heavily as the load drops, but at the same time the excess air content tends to rise.

With gas engines, similar curves are given within a range of 600 to 900 deg. fahr. exhaust temperature and 100 to 200 per cent excess air, varying from 0.50 to 2.75 lb. of water from and at 112 deg. fahr. per b.h.p. hr. Thus a typical gas engine running at 800 deg. fahr. exhaust and 150 per cent excess air will give an evaporation of approximately 1.90 lb. from and at 212 deg. fahr. per b.h.p. hr. Normally, the Spencer-Bonecourt boilers are built for pressures of 60, 120, and 160 lb. per sq. in., but they can be constructed for any pressure required.

Direct Firing with Roller Mills and a Slagging Furnace

By J. B. CRANE* and A. C. FOSTER*

The September 1930 issue of COMBUSTION contained an article describing an installation at the Monessen Plant of the Pittsburgh Steel Company, in which roller mills are used in conjunction with the direct-fired method of burning pulverized fuel. The present article describes a similar application at the Springdale Station of the West Penn Power Company. In this plant a slagging furnace is used. Both of these developments are of comparatively recent origin and the results thus far secured would seem to indicate that they will play an important part in steam plant practice of the future. The authors present operating data and offer conclusions as to the significance of the results obtained.

THE West Penn Power Company has made a noteworthy contribution to the art of steam generation in the equipping of No. thirteen boiler at its Springdale Station, near Pittsburgh.

The boiler is of the cross drum, sectional header type, equipped with a superheater and an economizer, the boiler containing 16,500 sq. ft. of heating surface.

In 1929, the engineers of Sanderson and Porter and of the West Penn Power Company, in conjunction with the engineers of Combustion Engineering Corporation, developed a design incorporating the following novel features:

1. Roller mills for direct firing.
2. A slagging bottom with an all water-cooled furnace.

The general arrangement of the boiler and furnace is shown in Fig. 3, and the application of roller mills in Fig. 1.

Heating surfaces and other details are as follows:

Boiler	16,500 sq. ft.
Slag Screen	922 " "
Front Wall	725 " "
Rear Wall	870 " "
Two Side Walls	1,186 " "
Total Water H. S.	20,203
Economizer	10,700 sq. ft.
Superheater	3,625 " "
Pressure per square inch	350 lb.
Steam temperature	650 deg. fahr.
Feed Water to boiler from economizer	300-310 deg. fahr.

*Combustion Engineering Corporation, New York

The furnace side walls are constructed of fin tubes. Some engineers had expressed doubts about the practical operation of such walls on account of the difficulty of maintaining the temperature at the bottom of furnace for proper tapping of the slag, but no difficulty of this kind has been encountered when the boiler is operating above 200,000 lb. of steam per hr. The furnace is tapped at 7 A.M. and 7 P.M. It requires from two to five minutes to start the flow of slag, and forty-five minutes to one hour to complete the tapping. The fusing temperature of the ash is 2350 to 2450 deg. fahr.

An additional slag screen was placed at the top of furnace to insure a low temperature of the gases entering the boiler tubes and to prevent slagging on the tubes. This arrangement has been successful and provides the ideal condition for a slagging furnace, namely, a hot bottom and a cool top.

The method of tapping slag is shown in Fig. 2. The slag spout was originally a solid casting. Trouble was experienced with this construction and a water-cooled design was finally worked out. This operates very successfully. There is no door on the spout. The stream is stopped by using a wet clay ball and this is pierced by a bar for tapping the furnace. A chute is run parallel to the slag stream. When

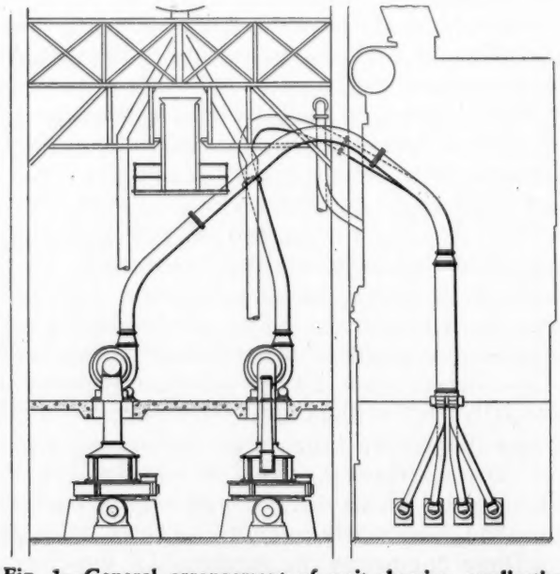


Fig. 1—General arrangement of unit showing application of roller mills.

tapping, the pipe is partly filled with running water. The water carries the slag into a water filled ash pit, and, as the slag hits the water in the pit, it takes a

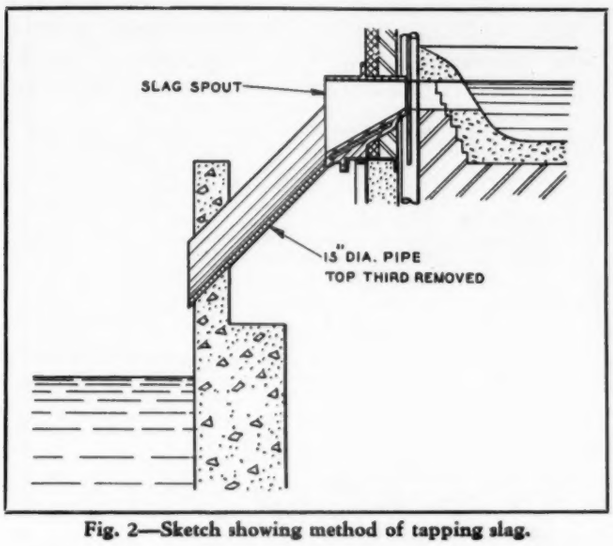


Fig. 2—Sketch showing method of tapping slag.

spiral shape and settles to the bottom. The flowing slag first takes a rectangular shape about 2 in. thick and 4 in. wide. This changes to a round stream about 2 in. in diameter. A market exists for this material for making cinder concrete, but in this case it does not pay to separate it, and it is used for fill along with the remainder of the ashes.

The log of this boiler is shown as follows:

MONTH 1929	HOURS IN OPERATION	PER CENT [1] RATING
June 15th (Started)	247½	381
July	553	399
August	579½	371
September	636	393
October	639	414
November[2]	712	400
December[3]	471½	385
January—1930	719	392
February	654	407
March[3]	337½	389
April	654	415
May	696	418
June	599	421

(1) Rating is based on the total heating surface except superheater. On the boiler alone the ratings would be increased 22 per cent, which would increase a rating of 400 per cent to approximately 488 per cent. The ratings given are the average monthly ratings. (2) Changes were made in burners to improve tapping at low ratings. No improvement was shown, and the burners were restored to the original condition. (3) Small auxiliary burners were installed to improve tapping at low ratings. With these burners the unit was run two and one half days at 171,000 lb. of steam per hr. During this period, slag was tapped at 7 A.M. and 7 P.M. each day. It required from six to ten minutes to start the flow, and thirty-five to forty-five minutes to finish tapping. The boiler and furnace were given a thorough overhauling at this time.

The capacities of the induced draft fans are the present limit to higher ratings.

The CO_2 varies from 15.2 to 15.3 per cent measured at the top of the first pass. For a short period the CO_2 was carried at 16 per cent, but secondary combustion occurred above the first pass.

When operating at a rating of 200,000 lb. of steam per hr. or less, considerable manual effort is required to tap the furnace and draw the slag. Studies are being made to improve this condition.

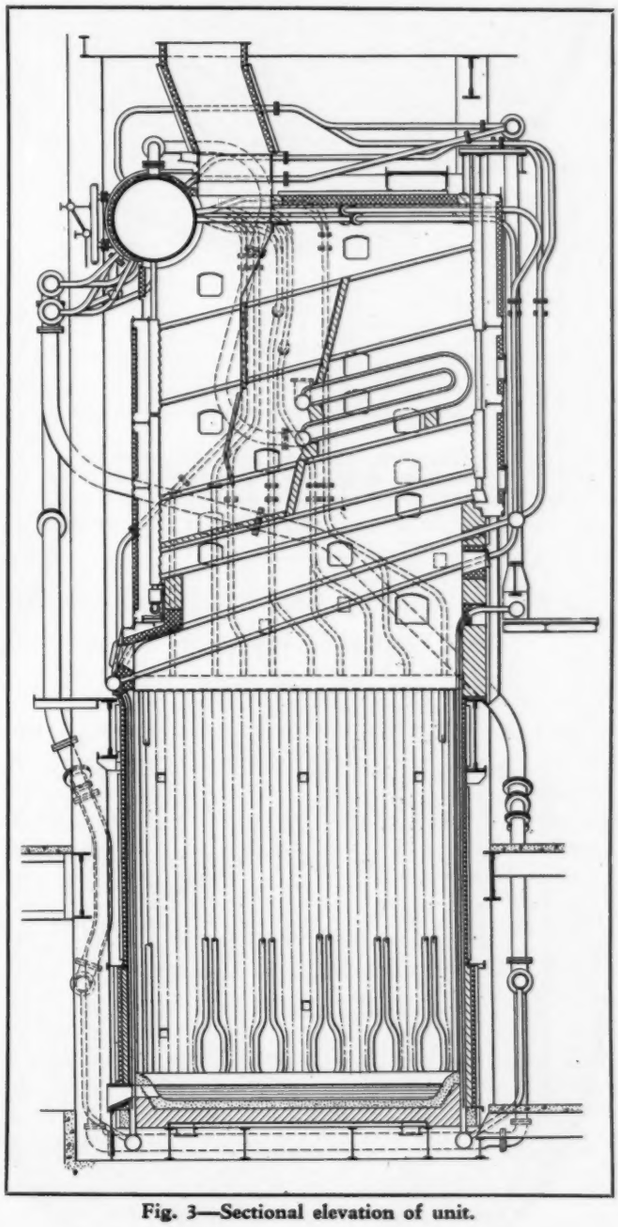
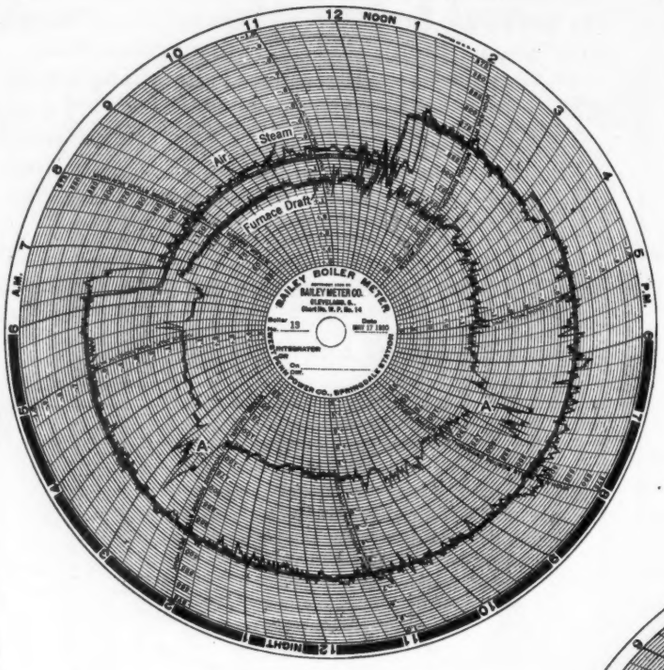
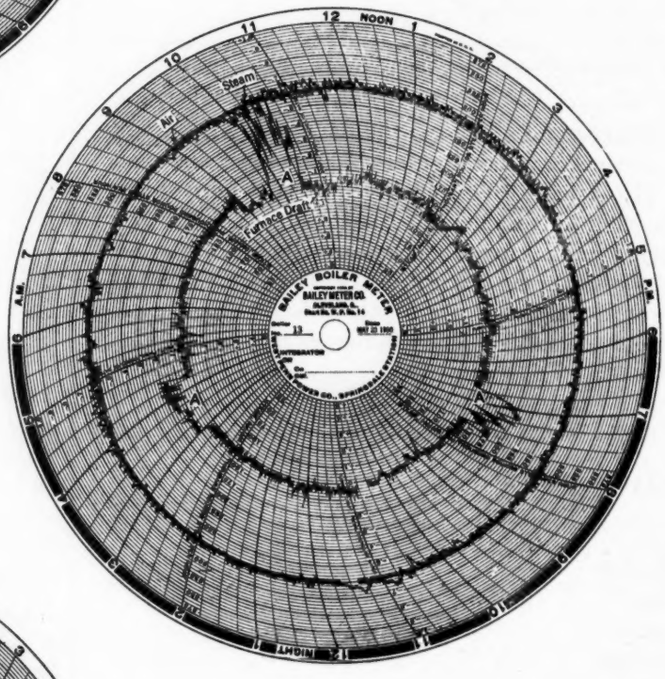


Fig. 3—Sectional elevation of unit.

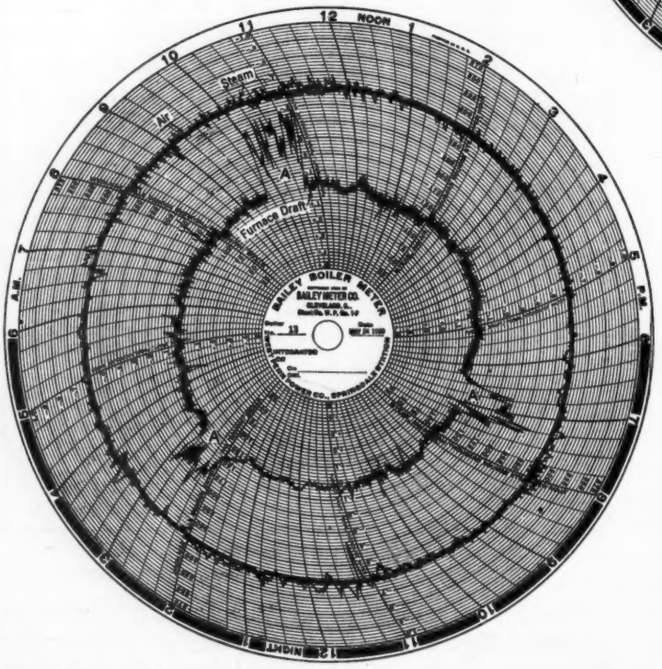
Charts, Fig. 4, for May 23rd and May 24th show the typical daily load on this boiler, while the chart for May 17th shows operation with one mill and with



Operating chart of May 17, 1930, showing operation part of the time with one mill and the remainder with two mills.



Operating chart of May 23, 1930, showing typical daily load conditions.



Operating chart of May 24, 1930, showing typical daily load conditions.

Fig. 4—Daily operating charts of No. 13 Boiler, Springdale Station, West Penn Power Company. The outermost solid lines show steam flow, the stippled lines show air flow and the inner solid lines, furnace draft. The draft fluctuations marked "A" are due to hand lancing of water screen.

two mills. The outside lines show steam flow and air flow. The inside line shows furnace draft. The dips shown are due to hand lancing of the slag screen.

No detailed tests have been run on this unit, but meter observations as shown on charts in Figs. 5, 6 and 7, obtained two weeks after boiler was placed into operation, will be of interest.

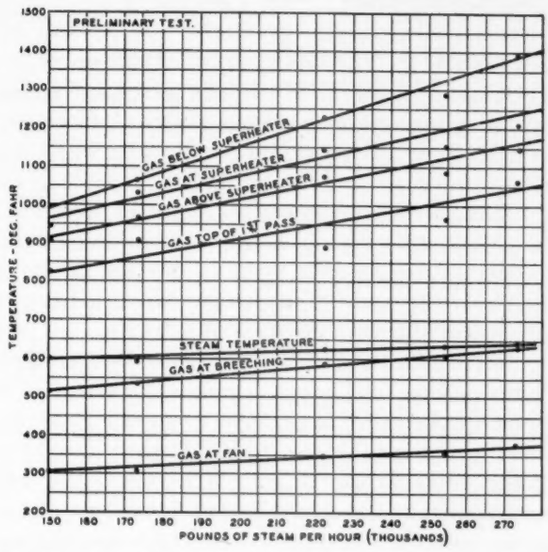


Fig. 5—Chart showing temperatures in various parts of unit.

This installation has demonstrated that roller mills can operate for long periods without shutdowns and are well adapted to the requirements of direct-firing of pulverized fuel; also that such applications possess the advantages of low power consumption and low maintenance.

With regard to the slagging furnace, it has been demonstrated that CO_2 need not be limited except to prevent secondary combustion; that removal of slag is simple and inexpensive; that the entire furnace volume can be used for combustion and that consequently less furnace volume is required than with the non-slagging type; and that the unit does not have to be shut down periodically to remove slag.

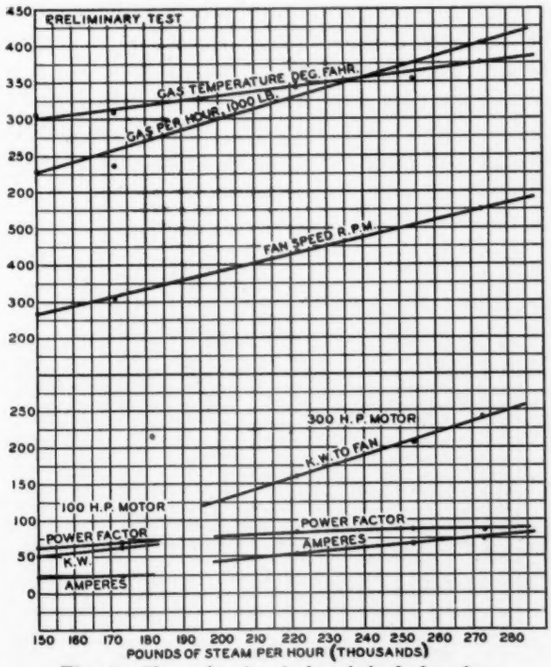


Fig. 6—Chart showing induced draft fan data.

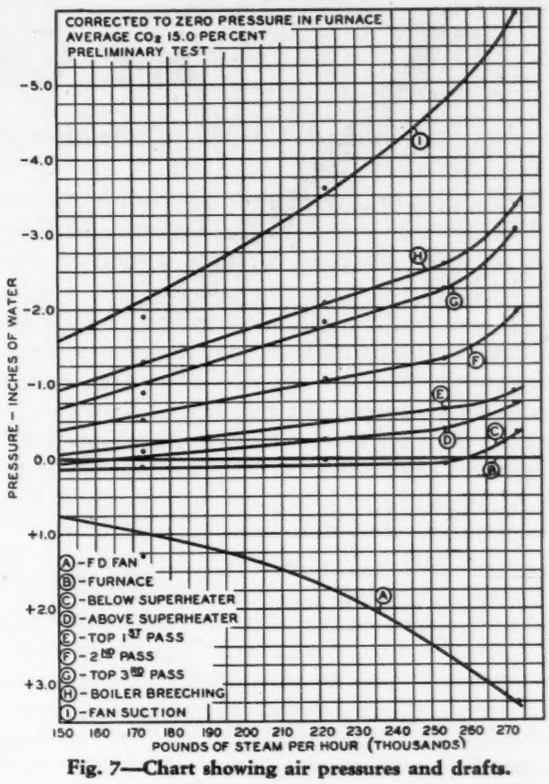

CORRECTED TO ZERO PRESSURE IN FURNACE
AVERAGE CO2 15.0 PER CENT
PRELIMINARY TEST
PRESSURE - INCHES OF WATER
A - F D FAN
B - FURNACE
C - BELOW SUPERHEATER
D - ABOVE SUPERHEATER
E - TOP 1ST PASS
F - 2ND PASS
G - TOP 3RD PASS
H - BOILER BREECHING
I - FAN SUCTION
POUNDS OF STEAM PER HOUR (THOUSANDS)

Fig. 7—Chart showing air pressures and drafts.

Heat Engines and the Second Law of Thermodynamics

(*Continued from page 39*)

Power," translated by Thurston, is well worth reading by engineers as an example of the appreciation of practical limitations as well as of theoretical possibilities in the production of mechanical power from heat. Clapeyron's paper "On the Motive Power of Heat" has also been translated into English and was published in Taylor's Scientific Memoirs, pp. 347-376, 1837. Clausius' book on "The Mechanical Theory of Heat," translated by Browne, gives the first exposition of the second law based on the mechanical theory of heat. Books on thermodynamics by Goodenough, Zeuner and others, discuss the second law with more or less clarity and completeness. The articles on thermodynamics in Glazebrook's Dictionary of Applied Physics and in the Encyclopedia Britannica also contain discussions of the second law.

The early history of the steam engine will be found in the article on the "Steam engine" in the Encyclopedia Britannica and also in Thurston's book, "A History of the Growth of the Steam Engine."

How Areas of Heat Absorbing Surfaces are Computed

By B. J. CROSS, Combustion Engineering Corporation, New York

THE rate of working of heat absorbing units is ordinarily considered to be measured by the amount of heat absorbed per unit surface in unit time. While this is approximately the case, a more correct measure of the rate of working is the amount of the heat supplying medium that is passed through the absorbing units. In the case of boilers, economizers and air heaters, the measure of their rate of working is the weight of gases passed through them. This is called the rate of mass flow or "mass flow" and is expressed in pounds per hour per square foot of free gas area. Both the draft loss and the rate of heat transfer vary with mass flow.

The small chart, Fig. 1 gives characteristic curves showing the relation between mass flow and the rate of heat transfer for different heat absorbing units. These curves do not represent exact values as the transfer rate will vary somewhat according to the size of tubes used and their spacing and also to some extent with the temperature.

When the initial temperature of the gases is known, the amount of heating surface may be computed for the desired final gas temperature at a given rate of mass flow.

The transfer rate is expressed in B.t.u. per hour per square foot surface per degree fahrenheit mean temperature difference, or:

$$\text{Transfer rate} — R = \frac{\text{B.t.u. per hour}}{\text{Area} \times \log \text{M.T.D.}}$$

If (a) is the initial temperature difference between the hot gases and the heat absorbing medium and (b) the final difference, the logrithmic mean temperature difference will be $(a—b) \div (\log_e \frac{a}{b})$.

For economizers, the final temperature of the water leaving the economizer must be calculated in order to obtain the initial temperature difference. This may be done by equating the heat lost by the gases to the heat gained by the water, or:

$Wg \times \text{sp. ht.} \times (T_1—T_2) = Ww \times \text{sp. ht.} \times (t_2—t_1)$

Wg is the weight of gases and $(T_1—T_2)$ the temperature drop. Ww is the weight of water and $(t_2—t_1)$ the temperature rise. All of these quantities are known with the exception of t_2 the final temperature of the water, for which the equation may be solved. The final temperature of the air from an air heater must be determined in the same manner.

The economic law of diminishing returns plays an important part in the design of heat absorbing apparatus. In a boiler, that part of the surface nearest the furnace gives the greatest return in the amount of heat absorbed. The temperature of the water in a boiler remains constant while the gases are cooled and approach in temperature the boiler surfaces, and the temperature difference for the transfer of heat is reduced. As more and more surface is added, the heat absorbed by each succeeding increment of surface becomes less and there is finally a point where the heat returned by an increment of surface does not justify the investment. This is the economic limit to the extension of heating surface of any unit.

Economizers are usually arranged on the principle of "counter flow". That is, the flow of water is in the opposite direction to the flow of gases. Thus, the warmest water is subjected to the hottest gases and the mean temperature difference between gas and water is maintained at a maximum. However, due to the great difference in specific heats, the temperature of the gases drops much faster than the temperature of the water rises.

The principle of counter flow finds a better application in air heaters. The specific heats of air and flue gases are not greatly different. The weight of air is however less than the weight of gases and the temperature rise of the air is greater than the temperature drop of the gases.

The chart on the opposite page has been prepared to facilitate the computation of mass flow. The curves of this chart give the weight of gases of combustion for the more common fuels for a heat release in the furnace of one million B.t.u. with varying excess air. When the hourly absorption in B.t.u. of a steam generating unit is known, the heat input to the furnace may be computed from the efficiency. The weight of gases per hour may then be obtained from this chart.

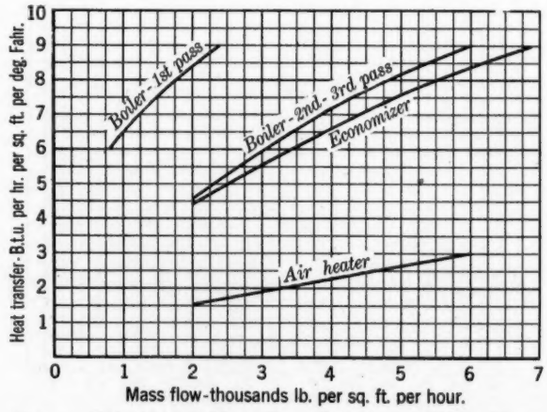


Fig. 1—Relation of Heat Transfer Rate to Mass Flow.

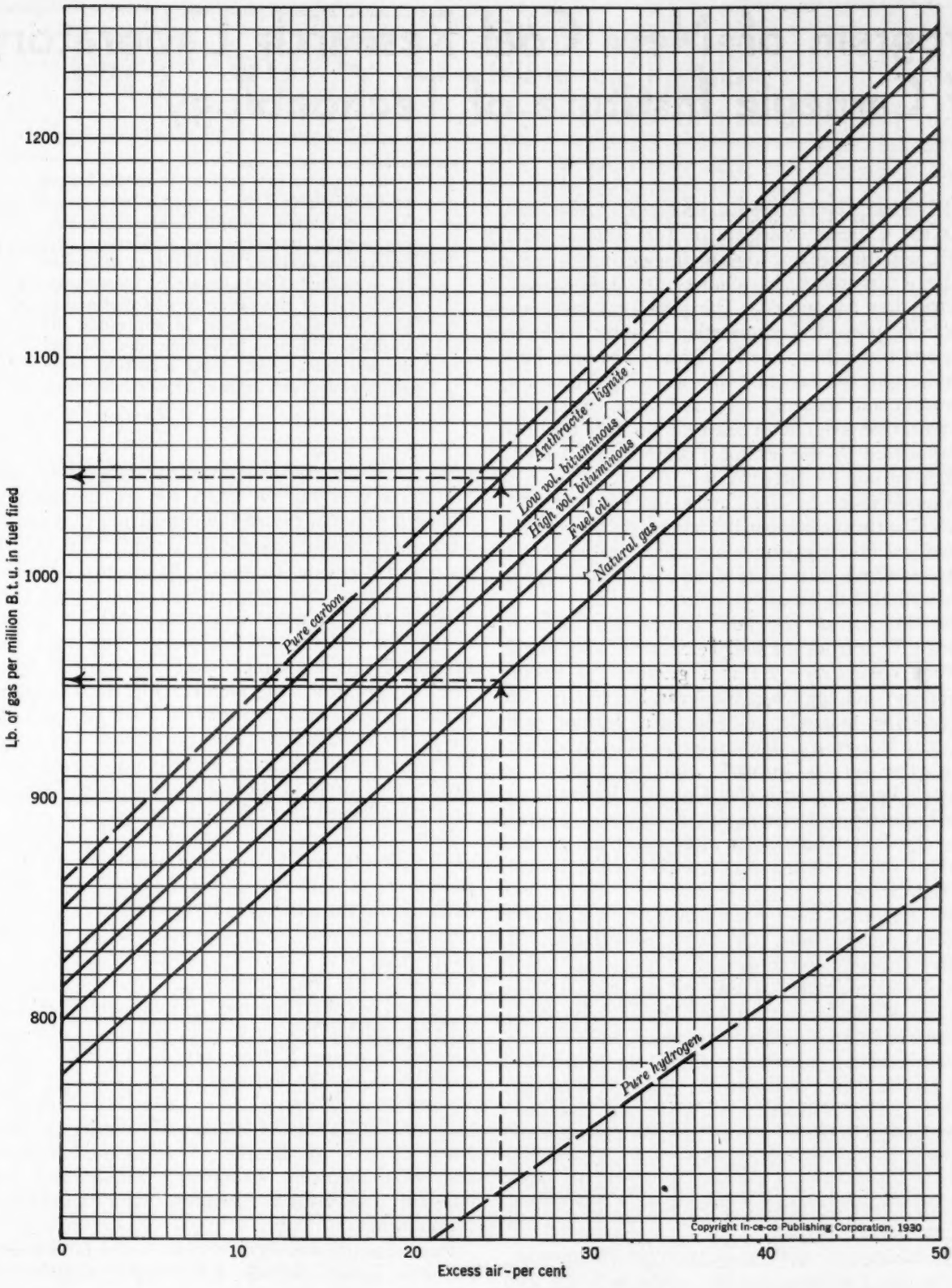


CHART FOR DETERMINING MASS FLOW IN POUNDS OF GASES OF COMBUSTION FOR ONE MILLION B. T. U. HEAT RELEASE IN FURNACE

No. 16 of a series of charts for the graphical solution of steam plant problems

Program of New Coal Research Laboratory of Carnegie Institute of Techonology

In response to a request from the Editor of COMBUSTION, Carnegie Institute of Technology has submitted the accompanying article, outlining the important program to be initiated this month at its recently organized Coal Research Laboratory. The work of this laboratory is destined to play a conspicuous part in improving the technique of coal utilization and increasing our knowledge of the manifold properties and characteristics of our basic fuel.

•

THE recently organized Coal Research Laboratory at the Carnegie Institute of Technology, Pittsburgh, will initiate its program of scientific study the middle of this month (November), Dr. H. H. Lowry, director, has announced. The gifts that made the laboratory possible became effective July 1 of this year, and since that time Dr. Lowry has been busy with the none too easy task of organizing this unique laboratory and securing a trained technical staff.

A tentative program of research has been outlined and approved by the technical committee. A study of high vacuum distillation will be one of the first to be undertaken by Dr. Lowry and his staff. Research into the mechanism of thermal decomposition of coal, an investigation which will deal with the reactions which take place when coal is subjected to heat, will also be an early project.

The director of the new laboratory comes to Carnegie Tech from the Bell Telephone Laboratories in New York City. He is a graduate of Peking University, and the Ohio Wesleyan University. He received his master's and doctor's degrees from Princeton University. He was engaged in the chemical warfare service in 1918, and did research in physical chemistry with the Western Electric Company Engineering Department, from 1920 to 1924. With the Bell laboratories after 1925, he worked principally on carbon and charcoal, gas absorption, and dielectrics.

Four scientists have been secured by Dr. Lowry up to the present time. Dr. D. Roberts Harper, 3d, former associate professor of Physics at Union College, Schenectady, is one of the staff. Other members of the present staff are Dr. J. F. Weiler, a graduate of Johns Hopkins University, and formerly in the research department of the Eagle Picher Lead Co., Joplin, Mo.; William B. Warren, who has studied at the University of Wisconsin, and who holds degrees from the University of California and Columbia University; and Bernard Juettner, a former research fellow in mining at Carnegie Tech, and a graduate of the University of Bonn, and the College of Agriculature, Berlin.

The laboratory will be located in Engineering Hall on the Carnegie campus. This building also houses the bureau of metallurgical research. Equipment and offices will be new and of the latest design.

The announcement of the laboratory was made by Dr. Thomas S. Baker, president of the Carnegie Institute of Technology in May 1930. The Buhl Foundation of Pittsburgh was the largest single donor to the laboratory fund, giving $50,000 at the outset for the equipment of the laboratory, and $25,000 a year for five years for its maintenance. This gift was made with the stipulation that certain additional amounts should be secured. Through the energy of President Thomas S. Baker, this condition was soon met. Six large industrial concerns came forward with financial assistance totalling $50,000 a year for a period of five years. The firms that furnished this assistance were the United States Steel Corporation, the General Electric Company, the Koppers Company, the New York Edison Company, the Standard Oil Company of New Jersey, and the Westinghouse Electric and Manufacturing Company. The totals of these gifts amount to $425,000 to be contributed over a five-year period.

Two committees will assist in the administration of the laboratory. An advisory board, consisting of prominent men of affairs, will be selected to aid in determining the policies to be followed. A technical committee, including representatives of the companies that have contributed toward the support of the study, has been appointed. This committee is composed of John Johnston, United States Steel Corporation, New York City; F. P. Wilson, Jr., General Electric Company, Schenectady, N. Y.; F. W. Sperr, Koppers Company, Pittsburgh; M. S. Sloan, New York Edison Company, New York City; Robert T. Haslam, Standard Oil Company of New Jersey, New York City; S. M. Kintner, Westinghouse Electric and Manufacturing Company, Pittsburgh; and Howard N. Eavenson, Eavenson, Alford and Hicks, Pittsburgh.

Regarding the research program of the laboratory, President Baker made the following statement:

"As for the work of the laboratory, I can only say that we shall undertake fundamental research in coal. There is no laboratory in this country at the present time that is doing the work that we have in mind. We shall not duplicate what is being done in the great industrial laboratories or in those of the Bureau

(*Continued on page 61*)

NEWS

Pertinent Items of Men and Affairs

The Permutit Company and Ward-Love Pump Corporation Merge

COMBINED assets of more than $4,000,000 are represented in the organization of General Water Treatment Corporation as a holding company to merge the interests of The Permutit Company, New York, and the Ward-Love Pump Corporation, Chicago, both manufacturers of equipment and systems for the softening and purification of water.

W. Spencer Robertson, president of The Permutit Company, will be president of the new corporation and Francis N. Bard, president of the Ward-Love Pump Corporation, will be chairman of the board of directors.

The Permutit Company was the pioneer in the zeolite water softening industry in this country and is the owner of basic patents covering the apparatus and the zeolites used in this process under which it has granted licenses both here and abroad. Its plants are located at Brooklyn, New York, and at Birmingham, New Jersey, where it also has large deposits of natural zeolites. In addition to its executive offices in New York City it has twenty-three sales offices strategically located throughout the United States. The Ward-Love Pump Corporation has two plants at Rockford, Ill., and executive offices at Chicago, Ill. It enjoys unusual facilities for the distribution of its products through the Crane Company, manufacturers and distributors of plumbing supplies with over one hundred branches in the United States

Installations of water-softening apparatus in the United States are proceeding at the rate of 25,000 units yearly, according to Mr. Robertson. Mergers in the industry have been frequent, The Permutit Company in recent years having acquired water-softening interests from the Kennecott Company, Borromite Company, Wayne Tank & Pump Co. and Paige & Jones Chemical Company.

•

B. F. Sturtevant Company, Hyde Park, Boston, Mass., has issued an attractive brochure entitled "An Air Castle" which gives a brief sketch of the history of the company from its founding in 1864 to date.

•

Bigelow-Liptak Corporation, Detroit, Mich., manufacturer of refractory arches and walls, has appointed Charles C. Plummer district sales manager at Chicago. Mr. Plummer was formerly Chicago district manager for R. H. Beaumont Company, Philadelphia.

Oil Well in Ocean Is a Record Producer

An oil well located in the Pacific Ocean, farther from shore than ever before attempted, has proven to be the greatest producer ever brought in under control in the California oil field.

This well is in the Elwood field, a Pacific Western Oil Company property near Santa Barbara, California, and is more than a quarter of a mile from land.

The initial flow of 6,400 barrels a day of 34.4 gravity oil is reported by the operators to have increased to 13,500 barrels daily.

•

The Mountain States Power Company recently opened its new $1,000,000 power plant at North Bend, Ore., with several thousand people attending the formal opening. The hog fuel used at this plant is obtained from local lumber mills and is delivered by a fleet of six barges owned and operated by the power company. Clam shell buckets are used to unload the wood into conveyors which elevate it to bins located above the furnaces.

•

James W. Owens, formerly director of welding at the Newport News Shipbuilding and Drydock Co., Newport News, Va., has joined with Messrs. Prof. C. A. Adams, C. A. McCune, J. H. Deppeler, Leon S. Moisseiff, and A. V. DeForest in organizing the Welding Engineering and Research Corporation, 25 West 43rd Street, New York, N. Y.

•

Fuller Lehigh Company, Fullerton, Pa., manufacturer of furnaces and pulverized coal equipment, announces that its Cincinnati office was moved October 1st from the Traction Building to the Carew Tower, Cincinnati, Ohio. H. E. Martin is district manager.

•

The Foxboro Company, Foxboro, Mass. manufacturer of industrial instruments announces the appointment of C. C. Fuller as New York district manager to succeed the late W. W. Patrick. The New York district office is located at 50 Church Street, New York City.

•

The Bernitz Furnace Appliance Company has appointed Fred G. Schneeberg, Jr., as New York district sales manager with offices at 350 Madison Avenue, New York City.

Mr. Schneeberg succeeds E. R. Jefferson who recently resigned from the Bernitz organization to enter the partnership of Striegel & Jefferson, manufacturers' agents at New York.

What Constitutes "Immediate Loss or Damage" Within Terms of Boiler Insurance Policy

Here is an interesting point in the interpretation of boiler insurance policies, involving the question of the extent of liability indicated by the term "immediate loss or damage." As the author points out, the judgment rendered in the case cited does not constitute a hard and fast rule since it was based largely on the particular facts of record, but it does serve to indicate the general attitude of the courts in questions of this character.

By LESLIE CHILDS, Indianapolis, Ind.

AS a general rule, explosion insurance policies covering boilers restrict the liability of the insurance company to the immediate loss or damage caused by an explosion. In other words, an insurance company may be willing to assume the risk of explosion, but in order to protect itself from liability from collateral loss, which may follow or precede an explosion, the above or a similar clause may be resorted to.

In the light of this, the question of what will constitute immediate loss or damage, within the meaning of this phrase as used in boiler insurance policies, becomes one of interest. And, while the point has been much litigated, it cannot be covered by a general rule because each case of this kind has necessarily been decided upon its facts. However, as an example of judicial reasoning on the question, the Maryland case of Hartford Steam Boiler Inspection & Insurance Company v. Henry Sonneborn & Company, 54 Atl. 610, may be examined with profit.

In this case the defendant issued an insurance policy covering certain boilers owned by the plaintiff. The policy contained, among other things, the following provision in respect to the kind and extent of the protection afforded:

"Against all immediate loss or damage, except by fire, to the property of the assured, [plaintiff] or to property of others for which the assured may be liable, wherever located, caused by the explosion, collapse or rupture of either of two horizontal steam boilers, on the premises of the assured."

While this policy was in force, the cast-iron elbow of the blowpipe of one of the insured boilers exploded, and large quantities of heated steam escaped, damaging certain goods in the plaintiff's building. Immediately following this, the heat from the escaping steam melted the heads of an automatic sprinkler system, in the building, which released large quantities of water, and thereby caused an additional loss by the wetting of merchandise in the building.

The defendant conceded its liability for loss directly caused by the steam escaping following the explosion, but denied liability for the loss caused by the water from the sprinkler system, on the ground that it was not an immediate loss, within the terms of the clause quoted heretofore. In other words, the defendant contended that the loss caused by water resulted from an intervening cause, i.e. the sprinkler system, and was not directly and immediately due to the explosion.

Upon the trial of the cause, a judgment was rendered in favor of the plaintiff. From this the defendant appealed, and the higher court in reviewing the record, in part, said:

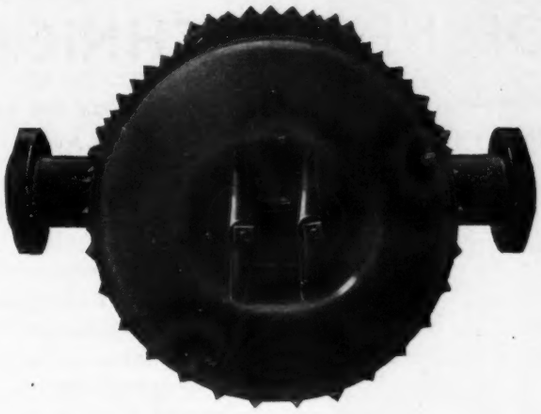
"The undisputed facts show that the explosion of the boiler in the cellar was the direct and efficient cause of the damage and loss to the property. The escaped steam from this boiler, by reason of the heat, melted the solder on the sprinkler heads, and set in motion the water which caused the damage. The witness Sonneborn testified that there was in the basement of the building at the time he moved into it, and when the policy was effected, what is known as the automatic sprinkler system for the extinguishment of fire, and this system was almost indispensable in mercantile establishments.

"He described it as consisting of a series of pipes which run along the ceiling; that these pipes were charged with water, and are fitted with iron jets, with glass heads on them; that the heads are soldered with a certain solution, which will melt at a certain degree of heat; that as soon as the solder is melted the glass heads fall off, thus opening the jet and permitting the water to come out and fall on merchandise below, protecting it from fire; and that escaping steam would be hot enough to melt the solder. * * *"

Following the above review of the record, the court turned to the question of whether or not the loss, as described, constituted an immediate loss resulting from the explosion, within the terms of the explosion policy. In stating its conclusions on this question, the court reasoned as follows:

"The word 'immediate', used in reference to 'loss and damage', in a policy of insurance, must be given a reasonable construction; and it is held to mean

(*Continued on page 61*)



COCHRANE

Steam Purifier

for 650 lb. Boiler

THIS is one of two 8-in. Cochrane Steam Purifiers supplied to a paper mill to intercept water and sludge carried over from 650-lb. boilers.

The steam pressure drop through the Cochrane Steam Purifier is practically negligible, and, due to the self-cleaning characteristics, does not increase with length of service.

The Cochrane Steam Purifier completely protects superheater surfaces, steam lines, governor valves and turbine parts against the action of moisture and solid matter brought over from the boiler by priming or foaming. It handles successfully the heaviest overloads, even where over 50 per cent by weight of the mixture leaving the boiler is water and sludge.

As the Purifier is EXTERNAL to the boiler, the full capacity of the steam drum to take care of water level fluctuations and to effect primary separation remains unimpaired.

The Cochrane Purifier is self-cleaning and requires no attention.

Ask for Cochrane Bulletin IC-677.

COCHRANE CORPORATION

3160 North 17th Street — Philadelphia, Pa.

473

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Generating Stations

By Alfred H. Lovell

THE purpose of this book is to show the application of economic principles to the broad engineering problems of electric generating station and transmission design, in selecting apparatus, proportioning details in an assembly, and in balancing initial and subsequent costs.

The treatment presupposes a knowledge of direct- and alternating-current machinery and circuits, together with fundamental training in mechanical and hydraulic engineering.

Attention is given to the vital interrelation of the mechanical and electrical elements in the design, with detailed analyses of those special features for which the electrical engineer alone is responsible.

Detailed analyses are given of the economic factors involved in the design of a number of existing power stations. Among the plants thus analyzed are three of the Detroit Edison Company's hydro-electric stations and the Trenton Channel and No. 3 Delray steam plants of the same company. Problems are also included which enable the reader to make practical application of the principles discussed.

This book will be especially helpful to engineers whose business and economic background is limited. Today this background is particularly necessary for the designing engineer who must use the cold judgment of the business man "to get the greatest possible value out of every dollar spent" and restrain his enthusiastic optimism for the very latest, most efficient machine available. The construction budgets are so large that many millions of dollars may be spent without justification if all the elements of cost are not considered. The more attractive operating efficiency must be weighed against the greater fixed charges which amount to a sum surprisingly large to those who have not given them detailed study. More than ever before, new methods and changes in design must justify themselves in the total energy cost per kilowatt-hour at the switchboard and the point of delivery.

The following chapter headings indicate the nature and scope of the volume: Elementary Principles of Corporate Finance; Cost of Stations; Economic Decay (covering physical depreciation, tests for obsolescence, etc.); Power Plant Load Curves; Economic Conductor Section—Power Distribution Systems; Power Plant Location; Bus Systems and Current-Limiting Reactors; Oil Circuit Breakers and Their Applications; Introduction to Single-Phase Short-Circuits; Protective Relays and Their Applications; Transmission Lines with Synchronous Condenser.

The size of the book is 6 by 9, with 360 pages and a comprehensive subject index. The price is $4.00.

Coal Carbonization

By R. Wigginton

IN the preface to this book, the author, a British engineer, states that his main objective is to give an outline of the chemistry of coal carbonization, as far as it is at present understood, from an academic rather than from a technical standpoint.

While there is some reference to the work done by practically all the pioneers in this field, both European and American, the author deals chiefly with the work done at Sheffield and elsewhere by Prof. R. V. Wheeler of England.

Chapters are devoted to the early history and later development of coal carbonization, the action of heat on coal, coal gas, ammonia and its recovery, coal tar and the formation and properties of coke.

The book contains 287 pages and is 6 by 8½ overall. The price is $6.50.

Formation and Properties of Boiler Scale

By Everett P. Partridge

THIS is a 170-page report of research work on the subject conducted by the Department of Engineering Research at the University of Michigan.

This report is intended to be a complete review of the information available up to the year 1930 concerning the formation and the properties of boiler scale. It deals with the effects of scale upon boiler efficiency and boiler metal temperature; the chemical and crystallographic determination of scale constituents; the respective solubilities of these constituents in simple solutions, and the possibility of calculating solubility equilibria in complex solutions; the method and rate of formation of scale; and concludes with a brief summary of contemporary methods of scale prevention.

The volume is bound in heavy paper covers and the price is $1.00.

A Standardized Steam Generating Unit

(Continued from page 34)

that their coal streams discharge between and together with the secondary preheated air, resulting in the desired intimate mixture of coal and air.

The direct-fired method of burning pulverized fuel is used, the unit being served by two Raymond Impact Mills, each having a capacity of 8,000 lb. of coal per hr. Each mill will supply the burners in opposed corners. For low ratings of the generator, one mill only need be in operation and, with the burners opposing one another, stable ignition is assured.

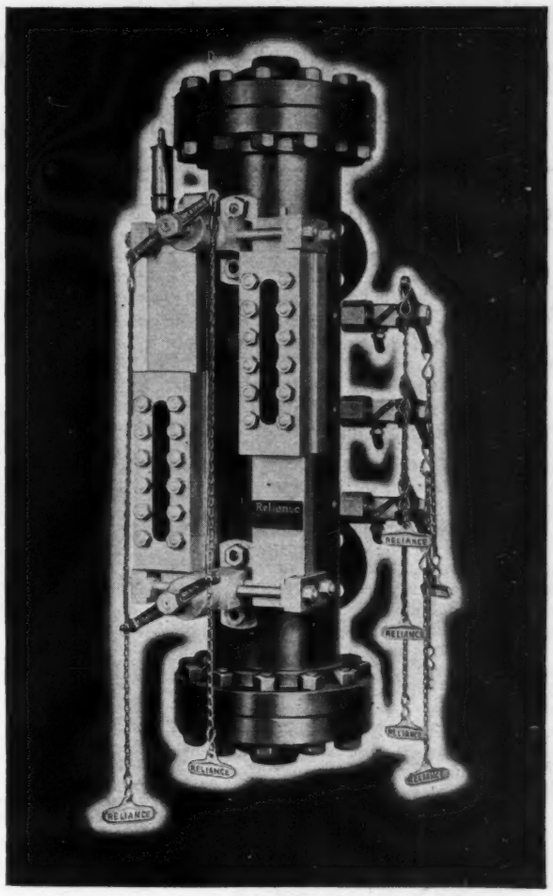
This unit has been designed for a safe working pressure of 825 lb. per sq. in. At the maximum rating guaranteed, the unit will produce 150,000 lb. of steam per hr. at 750 lb. pressure and at a temperature of 750 deg. fahr. The efficiency at the maximum guaranteed rating will be 85 per cent. The feed water temperature to the generator is 212 deg. fahr. At the peak load 15,000 lb. of coal per hr. will be burned, which is a liberation of 27,000 B.t.u. per cu. ft. of furnace volume per hr. The total heating surface is 15,671 sq. ft., which includes 2,878 sq. ft. of radiant surface. At the maximum operating range, preheated air at a temperature of 530 deg. fahr. will be available at the burners. Primary combustion air is first delivered to the mills for mill drying of the coal.

For the induced draft service, a slow speed steel plate fan, with renewable liners and designed for 6 in. static pressure, will be used. Forced draft service will be provided by a medium speed, multivane fan designed for 9 in. static pressure.

As previously mentioned, the steam generator described herein is one of five standard generators designed for capacities ranging from 150,000 to 400,000 lb. of steam per hr. The design is adaptable to any desired pressure. The capacity of each of these units will, of course, vary, depending on the grade of fuel used and also on the nature of the load. With a high grade coal, such as Pocahontas, higher rates of heat liberation are possible on continuous, daily or hourly loads than with a lower grade Middle Western coal.

In each of the five sizes of units, the generator heating surface face has been definitely established. The superheater surface, however, is variable, depending upon the superheat desired. Also, the air preheater surface is variable, depending upon the temperature of the gases leaving the convection surface and the amount of preheat desired.

In the first part of this article, it was mentioned that a number of steam generators of this design have been sold abroad. Of these, four will be of the 250,000 lb. size, operating at 325 lb. pressure and 788 deg. fahr., and three of the 150,000 lb. size, one of which will operate at 462 lb. pressure and 788 deg. fahr. and the other two at 270 lb. pressure and 700 deg. fahr.



The Reliance Forged Steel High Pressure Column for working steam pressure of 750 pounds. It is equipped with the Reliance 1500 pound water gauge and gauge cocks, and Reliance Monel Floats.

Reliance Columns

Make High Pressures Safe

RELIANCE SAFETY WATER COLUMNS guard the higher pressures of today, 750 pounds and up, with as much certainty as they guarded the 50-pound pressures of four decades ago. Reliance engineering *has kept pace.*

The Reliance Float has had much to do with rendering these modern pressures safe. Out of more than 20,000 Reliance Monel Floats already in service, not one has failed for any reason whatsoever. Out of a total of several hundred thousand Reliance copper, nickel and monel floats now in service, only a small fraction of 1 per cent needed replacement in the past year. *There is no float problem with Reliance Columns.*

Not one Reliance Column has ever been known to fail in an emergency. Be sure—specify Reliance.

See us at the Power Show, Booth No. 82

The Reliance Gauge Column Company

5942 CARNEGIE AVE., CLEVELAND, OHIO

Reliance

TRADE MARK REG. IN U.S. PAT. OFF.

SAFETY WATER COLUMNS

NEW EQUIPMENT

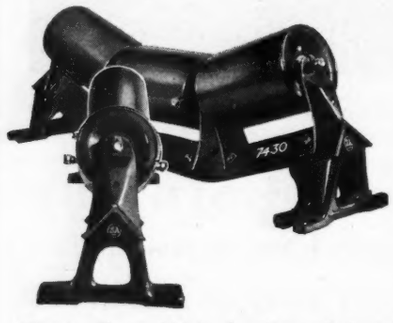
of interest to steam plant Engineers

Simplified Belt Conveyor Carrier

A NEW roller bearing belt conveyor carrier, known as the "Pacific Type," has been developed by the Stephens-Adamson Manufacturing Company, Aurora, Ill.

As the accompanying illustration shows, this carrier is of the three roller, 20 degree trough design now favored by many engineers. The construction is of heavy gage pressed steel, with the single exception of the end stand castings, making the carrier light in weight, strong, rigid and practically unbreakable.

Each roller turns upon two Timken tapered roller bearings housed within an inner hub of steel tubing and protected from dust and moisture by an intermeshing labyrinth grease seal for each bearing. The tapered roller bearings used are large in size and are arranged to carry end thrust as well as radial loads. The inner hub extends the full length of each roller and prevents any chance for misalignment of bearings. A unique arrangement has been provided for adjusting and setting the bearings for proper clearance. Positive lubrication is insured by an individual Alemite fitting for each bearing.



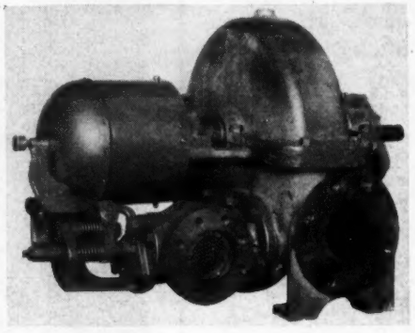
Every roller, with its bearings, shaft and grease seals, is a self-contained unit that can easily be interchanged with any other roller without disturbing the bearing adjustment. The cross member is a single structural steel angle, formed and punched to eliminate all but one standard pressed steel bracket that is interchangeable for all sizes of carriers. The angle is self-cleaning and eliminates any tendency for material to collect and hinder the free action of the rollers.

The "Pacific" carrier is built in a range of sizes for conveyor belts from 18 to 48 inches wide.

New Mechanical-Drive Turbine

A NEW small mechanical-drive noncondensing steam turbine for driving centrifugal pumps, fans and similar industrial equipment operating in general at speeds between 1750 and 3600 r.p.m. and rated from 5 to 50 hp., has been announced by the General Electric Company, Schenectady, N. Y.

The new turbine which bears the type designation D-57, is built only as a single-stage machine and has two rows of revolving buckets. It follows the design of the standard line of G. E. mechanical-drive turbines and although simple in construction embodies dependability and reliability. The wheel casing is split horizontally for easy access to the internal parts, and the steam and exhaust pipes are connected to the lower half of the machine.



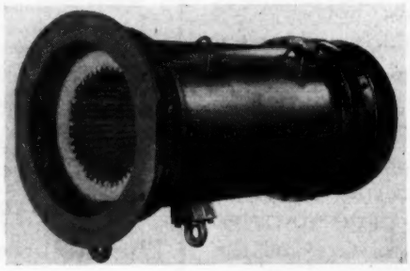
A new design of centrifugal governor with weights pivoting on knife edges operates with very little friction and provides proper speed regulation. An independent emergency governor is included as standard equipment.

Natural Draft Gas Burner

THE Denver Fire Clay Company, Denver, Colo., has announced the D. F. C. gas burner designed to burn gas efficiently under either heating or power boilers. It is of the atmospheric type operating with natural draft and no auxiliary apparatus is required to supply air for combustion.

The burner consists of four parts—a nozzle, a throat, a manifold and an air shutter.

The nozzle and throat are formed in refractory tile. The nozzle is designed with sharp longitudinal edges or ridges in the tile. These ridges run in the direction of the gas and air flow and become incandescent, accelerating combustion and preventing the flame blowing away from the burner nozzle no matter what draft or atmospheric conditions might arise. They permit the immediate opening of the burner to full capacity without puffing or vibrating under any furnace condition.



Because of the accelerated combustion, a larger amount of gas can be burned per cubic foot of combustion chamber volume.

The throat of the burner is shaped and proportioned to form a Venturi tube, so the gas jet produces a positive injector effect. The combination of these two features permits the liberation of a large amount of heat per unit of furnace volume.

The tile forming the nozzle and throat are dove-tailed into an iron casting to which the burner manifold is attached. This manifold is of welded construction and is designed to give an equal flow of gas to each orifice or jet. The gas orifices are removable so that the initial installation can be easily adjusted to suit the draft and pressure conditions.

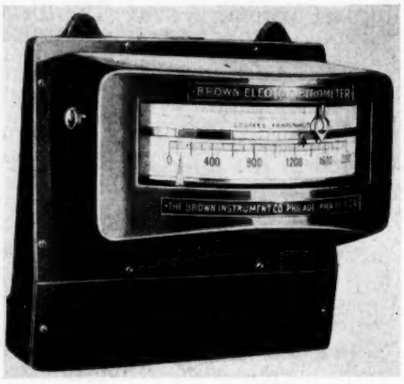
The air shutter is arranged for either hand or automatic control. The shutter is attached in a manner which permits of its ready removal without disturbing the remainder of the burner. It consists of louvers connected by rigid links to a handle containing a setting device which consists of a screw which clamps a shoe to a quadrant at any desired position. For automatic control the locking screw is turned back far enough to make it inoperative.

A permanent pilot of special design is furnished with each burner unit. The burner has been designed for natural gas and will operate under a wide range of pressures, tests having shown excellent results under pressures as high as 50 lb. per sq. in. The arrangement of the multiple Venturi throats and air shutter gives a perfect mixture to each unit and excellent efficiencies have been obtained over the entire range of burner capacity.

Pyrometer Controller

A NEW Indicating Pyrometer Controller known as Model 801 has been announced by the Brown Instrument Co., Philadelphia.

This instrument, which can be supplied as an automatic control pyrometer, resistance



thermometer, tachometer, or CO_2 meter, has the following advantages:

1. Reading observed directly on 6 in. scale.
2. Index on scale for setting to exact control point.
3. Control point easily adjustable.
4. All wiring terminals and motor enclosed.
5. Mercury switches up to 30 amperes capacity, eliminating the necessity of relay equipment. Make and break occurs in sealed glass tube. No danger of spark causing explosion.
6. Suitable for "on and off" or "three position" control through switches, valves, dampers, etc.
7. Available with patented safety device which opens furnace circuit if thermocouple or wiring fails, preventing burning out furnace.
8. High internal resistance, insuring accuracy.
9. Automatic internal compensation eliminating cold junction errors when instrument is supplied as a pyrometer.
10. Simplicity and ruggedness insures minimum of attention.

The control mechanism of Model 801 Indicating Pyrometer Controller combines the basic principles of the Brown Automatic Control Recorder with the new feature of mercury contacts for breaking high currents.

Fourth National Fuels Meeting Program Nearing Completion

The program for the Fourth National Fuels Meeting of the A.S.M.E. which will be held in Chicago, February 11 to 13, 1931, is rapidly nearing the stage where papers and authors for each session may be announced to the Engineering World.

The Fuels Division of the American Society of Mechanical Engineers, which has sponsored these national events since their inauguration in 1927, is making an unusual effort to develop the type of program best fitted to parallel the sessions of the Midwest Power Engineering Conference to be held during the same week. The procedure for the Fourth National Fuels Meeting will be somewhat different from that followed at the three previous meetings. Heretofore the meetings have started on Monday morning and have run four days with as high as three simultaneous sessions during some of the periods. The coming Meeting will start on Wednesday afternoon, and both the Fuels Division and the Chicago Section of the A.S.M.E., which is in charge of all local arrangements, have agreed that there must be no simultaneous sessions.

For the first time in the history of the meetings a parallel convention will operate during two days of the three-day event. However, both programs have been so laid out that there will be no conflicting sessions and the engineer interested in both fuels and power can arrange his schedule so that maximum results may be had.

Among the subjects included in the program in its present form are the following; each of which will be discussed by the most prominent authorities in the fields represented:

"Developments in Furnace Design"
"Developments in Pulverized Fuel Firing"
"Developments in the Small Stoker Field"
"The Use of Refinery Waste Fuels"
"The Use of Natural Gas and the Conversion of Coal Fired Furnaces to Gas"
"Boiler Efficiencies as Effected by Types of Fuels"
"Effect of Temperature on Rapidity of Combustion"
"Heat Absorption as Effected by Furnace Wall Materials"
"Selection and Coordination of Steam Generating Equipment"
"Design and Performance of Large Boiler Units"
"The Boiler Plant of the Future"
"Changes in Character of Mid-West Coals and Stoker Performances"
"Air Pollution"

Early announcements will present the complete program of these technical sessions and will give the names of the authors who will present papers on the general subjects listed above.

Don't Take Our Word For It—

Try R & E Cements in Your Own Plant

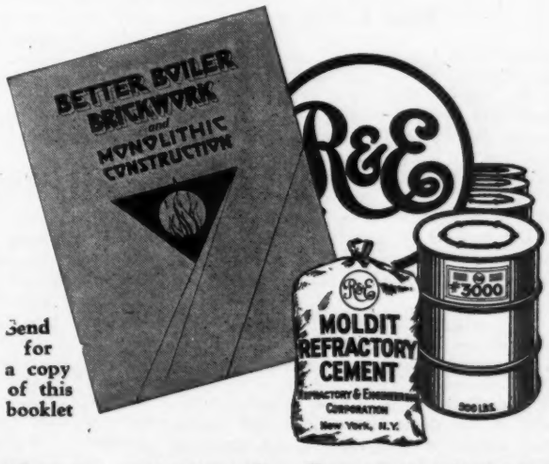
We claim that R & E Refractory Cements are most unusual. They last longer, cost no more and are just as easy to use as any other cements.

But don't take our word for it—try them in your own plant. Use a sample order as we recommend under this liberal, truthful guarantee.

OUR GUARANTEE

R & E Cements are guaranteed to give absolute satisfaction when used in the manner and for the purposes which we recommend. If, under these conditions, a cement fails to come up to your expectations, we will refund the purchase price.

If you don't want a sample order, you should at least have a copy of "Better Boiler Brickwork and Monolithic Construction." It's a booklet written in your language and easy to read. ***Write today!***



Send for a copy of this booklet

REFRACTORY & ENGINEERING CORPORATION
50 Church Street, New York, N. Y.

Warehouses in
Philadelphia Norfolk Baltimore Pittsburgh Boston Chicago

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine.

Blow-Off Valves

Catalog B-417 is a comprehensive exposition of modern blow-down practice and equipment. It covers the complete Yarway line of both Seatless (Sliding Plunger Type) Valves and Double-Tightening (Gate Type) Valves for all operating requirements. Various tandem arrangements as used by leading power plants are shown together with arrangements for continuous blow-down service. The advantages of grey iron, electric furnace and forged steel, bronze, nickel alloy and nitralloy in the construction of modern blow-off equipment for various operating conditions, are discussed. It is complete in engineering data, dimensions, operating instructions, prices of both valves and parts and is generously illustrated with photographs, sectional views and diagrams. It is cross indexed for easy reference, is well printed and substantially bound, 40 pages and cover, 8½ x 11—Yarnell Waring Company, Chestnut Hill, Philadelphia.

Boiler

The Union "L" type boiler, designed for low head room and limited space conditions is presented in a new bulletin. This new boiler is a three-drum, bent tube unit arranged to require the minimum in setting dimensions and brickwork. The two upper drums are located on the same horizontal center line to provide the maximum steam disengaging surface and to allow full steam liberation in the front drum. Monolithic baffles and full steel suspension are standard. Various setting arrangements for different methods of firing are shown and complete tables of dimensions are included covering the full range of sizes. 12 pages, 8½ x 11—Union Iron Works, Erie, Pa.

Boiler Baffles

Mono Boiler Baffles are described in a new bulletin. This baffling is monolithic and can be installed in any type of water tube boiler and set at any required angle to give the proper proportioning of gas passes. There are no joints to leak and tubes may be drawn and replaced without damage to the baffles. Typical arrangements of baffling are shown for various types of boilers and the method of installing Mono Baffles is illustrated. 16 pages, 8½ x 11—King Refractories Co., 1709 Niagara St., Buffalo.

Combustion Control System

The Askania System of automatic combustion control for steam boilers is comprehensively described in a new bulletin. The regulation of damper positions and drive motor speeds is effected by oil pressure servomotors which are similar in design to those used on turbine governors. A number of typical application arrangements, including stoker fired and pulverized fuel fired units, are illustrated diagrammatically and described.

Three charts are included to show the savings effected by replacing hand control with automatic control. 16 pages and cover, 8½ x 11—H. A. Brassert & Company, 310 South Michigan Avenue, Chicago, Ill.

Feed Water Heaters

Patterson Feed Water Heaters are presented in a new catalog. These heaters are of the instantaneous water tube type in which the heating surface comprises a nest of U Shaped seamless drawn copper tubing. Both ends of each tube are expanded into a forged steel tube header and each tube is free to expand and contract independently of any other tube. Positive circulation of the water insures high velocity and high rates of heat transfer. A wide range of sizes from 20 hp. to 1500 hp. is available in either vertical or horizontal types. 12 pages and cover, 6 x 9¼—The Paterson-Kelley Company, 101 Park Ave., New York.

Feed Water Treatment

"How to Increase the Efficiency of Lime and Soda Ash Softening Plants" is the title of bulletin No. 12 B, recently issued. The use of sodium aluminate with lime and soda ash is recommended because this combination not only produces superior coagulation, but materially aids in the reduction of encrusting salts to a lower range of hardness than is feasible with lime-soda ash treatment alone. Charts are included to show the improved operation resulting from the use of sodium aluminate. 8 pages 8½ x 11—National Aluminate Corporation, 6216 W. 66th Place, Chicago.

Gas or Powdered Coal Burner

The "A and D" Adjustable Orifice Burner, described in a new bulletin, is offered for burning gas or powdered fuel in industrial furnaces and under steam boilers. The burner is designed with an adjustable orifice so that uniform velocity and full turbulent mixing action of fuel and air may be maintained irrespective of the amount of fuel being burned. Numerous illustrations show the principle of design and several typical application arrangements are also presented. A table of sizes and capacities is included, 8 pages, 8½ x 11—The Ashmead-Danks Company, 7016 Euclid Ave., Cleveland, Ohio.

Humidity Recorder

Bulletin No. 880 describes the L & N Direct Reading Humidity Recorder. The usual psychrometric device measures the temperatures of wet and dry bulb thermometers in a current of air, but the observer must find the corresponding humidity from a table or chart showing the relationship. The unique feature of the new L & N instrument is that it records relative humidity directly. The theory on which the instrument is based and its application are clearly presented. 8 pages, 7¾ x 10½—Leeds & Northrup Company, Philadelphia, Pa.

Pyrometers

Brown Indicating Recording and Controlling Pyrometers are described in a new catalog No. 15 A. The general subject of pyrometry is covered in this comprehensive booklet and much information on heat measurement and control is included. The principles of pyrometer design, the details of construction and methods of application are presented. The booklet is printed in colors and 140 excellent illustrations are shown. A full size view of a recording type pyrometer, printed in five colors, is inserted. 100 pages and cover, 8 x 10½—The Brown Instrument Company, Philadelphia, Pa.

Steam Plant Equipment

The entire line of ADSCO products for the measurement and distribution of steam is shown in a new catalog. This range of apparatus includes expansion joints, condensation and steam flow meters, conduit, fittings, valves, traps, strainers and various types of heaters. Specifications and tables of dimensions are included to cover each type of equipment. 38 pages and cover, 8½ x 11—American District Steam Company, North Tonawanda, N. Y.

Water Level Indicator

A leaflet is available describing the McNeill Liquid Level Gage which has been developed to provide a reliable and accurate water level indicator that can be located wherever convenient, either near the boiler or at a distance. With modern high boiler settings the advantages of a water level indicator that can be located at the firing floor level, are apparent. The gage has been developed for steam pressures up to 600 lb. per sq. in. Since the instrument is not subjected to high temperatures the difficulties due to temperature changes are eliminated. 2 pages, 8½ x 11—Boiler Room Improvement Company, 4057 West Van Buren Street, Chicago, Ill.

Welded Pressure Drums

A new bulletin describes the HWW Hy-Pressure weld, a distinct development in the art of fusion welding. Tests have shown the weld to be stronger than the original plate and the weld resists corrosion better than the plate. All high pressure vessels made by this welding process are carefully annealed after welding to relieve fabricating stresses, then hydrostatically tested to double the working pressure and all seams struck with hammers at this pressure. Micro-photographs are included to show the structure of the fusion welds. 4 pages 8½ x 11—The Hedges-Walsh-Weidener Company, Chattanooga, Tenn.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

Boiler, Stoker and Pulverized Fuel Equipment Sales

Total figures to October 1, as reported to the Department of Commerce by the leading manufacturers in each industry

Boiler Sales

	Total 9 mo. 1930		Total 9 mo. 1929		Sept., 1929		Sept., 1930	
	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.
Water tube	906	4,815,193	1339	7,692,059	144	966,656	78	565,636
H.R.T.	739	1,002,906	1102	1,458,504	115	138,759	93	119,291

Mechanical Stoker Sales

Year and Month	Total		Type of Boiler			
			Fire-tube		Water-tube	
	No.	HP.	No.	HP.	No.	HP.
1929						
July	186	65,197	88	11,922	98	53,275
August	199	54,929	94	13,981	105	40,948
September	155	45,685	71	9,791	84	35,894
Total (9 mo.)	1,352	459,032	544	81,613	808	377,419
Total (year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
Total (9 mo.)	963	294,559	467	66,726	496	227,833

Pulverized Fuel Equipment Sales

Year and Month	CENTRAL SYSTEM			UNIT SYSTEM		
	No. of Pulverizers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped	No. of Pulverizers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped
1930	For Installation Under Water-Tube Boilers					
January	1	6	1,600	52	565	59,742
February	2	20	3,000	29	175	23,305
March	2	50	6,414	16	33	9,995
April	....	....	....	31	139	37,993
May	3	80	11,360	30	196	22,625
June	1	6	802	15	28	7,146
July	2	22	1000	12	29	20,424
August	....	....	....	4	13	1,454
September	....	....	....	24	112	18,729
Total (9 mo.)	11	184	24,176	213	1,290	201,413
	For Installation Under Fire-Tube Boilers					
January	....	....	....	6	35	965
February	....	....	....	2	13	305
March	....	....	....	3	3	450
April	....	....	....	3	3	780
May	....	....	....	....	....	....
June	....	....	....	....	....	....
July	....	....	....	....	....	....
August	....	....	....	3	3	712
September	....	....	....	6	3	900
Total (9 mo.)	....	....	....	23	60	4,112

TECHNICAL CE-CO PAINTS

Developed *to meet power plant conditions*

CE-CO paints, the product of over 50 years' experience and research, reduce the costly burden of plant maintenance.

Our Technical Department is always glad to assist in selecting the proper paint. Write for our recommendations.

A few* CE-CO *paints used in power plants

•

CE-CO Metal Preservative Paints
For all conditions.

CE-CO Engine Enamel
Not affected by oil, and stands frequent wiping

CE-CO Cement Floor Enamel
Dries quickly; not affected by oil or water

CE-CO Pipe Enamel
For preserving and identifying exposed pipes

CE-CO Stack Paints
In gray, buff, red, brown and other shades

Cecoloid Quick Drying Enamel
For interior and exterior equipment; also doors, trim, etc. Resists marring, chipping, water, chemicals

•

CE-CO Stack Lining
Eliminates brick lining—saves about 9 in. in exterior diameter of stack—reduces weight about 38 lb. per sq. ft.—saves about 2/3 cost of brick lining — forms a jointless lining. Easily applied.

CHEESMAN-ELLIOT CO., Inc.
Established 1876
Technical Paint Makers
639-647 Kent Avenue, Brooklyn, N. Y.
Works: Brooklyn, N. Y.—Williamsport, Pa.

CHEESMAN-ELLIOT CO., Inc.
639 Kent Avenue, Brooklyn, N. Y.
Please send me your bulletin describing:
- ☐ CE-CO Metal Preservative Paints
- ☐ CE-CO Heat Resisting Paints
- ☐ CE-CO Enamels
- ☐ CE-CO Stack Lining

FIRM .....
NAME .....
ADDRESS .....
POSITION .....

BOOKS

of Current Interest to Engineers

Exhaust Steam Engineering

By C. S. DARLING

431 Pages

This book is exceptionally rich in material of practical value. Every illustration, table or curve is precisely suited to the context. Explanations of engineering or scientific principles are brief and clear, and very many practical calculations of concrete examples are used to drive home the thoughts. This method of treatment makes this volume of special value as a handbook for the solution of steam plant problems. The subject matter will be as useful in the renovation of old plants as in the design of new ones. In his preface the author states that he has written from the viewpoint of the user and consulting engineer.

PRICE
$7.50

FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS

Price $3.00 — 808 Pages

This well known Cochrane reference book has been revised and enlarged. New matter has been introduced in the sections on Fuels, Combustion and Heat Absorption, and considerable material has been added on the subjects of steam and water measurements, water treatment and testing. As a handbook on these subjects, this volume is eminently practical and useful. Every steam plant engineer should have a copy. The third edition is being rapidly depleted. To assure your getting a copy without delay, send your order immediately.

FUEL ECONOMY IN BOILER ROOMS

By Maujer and Bromley

Price $3.00 — 308 Pages

Part one of this book covers principles of combustion, coal and flue gas analysis, calculations involved in determining boiler efficiency. Part 2 covers fuels and their utilization and firing methods, stoker operation and boiler settings.

POWER PLANT LUBRICATION

By W. F. Osborne

Price $3.00 — 275 Pages

A practical book for the power plant engineer explaining the physical and chemical properties of lubricants, their action under changing influence of heat, pressure, etc., and the methods of determining their relative values. The book shows the practical application of lubricants to the principal types of power plant machinery and gives specifications and standard tests.

HEAT TRANSMISSION BY RADIATION, CONDUCTION AND CONVECTION

By R. Royds

Price $6.00 — 238 Pages

This book is more analytical than the ordinary heat reference book. Dr. Royd describes his theory in detail, with complete experimental proofs. A thorough analysis of radiation and conduction precedes the chapters on convection.

MATHEMATICS FOR ENGINEERS

By R. W. Dull

Price $5.00 — 780 Pages

A mature treatment of mathematics for practicing engineers. A complete treatise on engineering mathematics from arithmetical computations to partial and multiple integration—a mature explanation for practicing engineers of the principles and methods of those phases of mathematics especially important in engineering work.

THE FLOW OF HOT GASES IN FURNACES

By W. E. Groume-Grjimailo

Price $5.50 — 399 Pages

This is a particularly informative and authoritative reference on the subject of combustion gases. Its contents include a practical discussion of the principles for the rational construction of furnaces. The reading and study of this valuable book should lead to many improvements in the art of heating and utilizing of heat.

Postage prepaid on all orders accompanied by remittance or amounting to five dollars or over.

IN-CE-CO PUBLISHING CORPORATION

200 Madison Avenue — New York, N. Y.

What Constitutes "Immediate Loss or Damage" Within Terms of Boiler Insurance Policy

(*Continued from page 52*)

direct or proximate cause, as distinguished from a remote cause. * * * In the case at bar the existence of the automatic sprinkler in the cellar was known to the company at the time of the issuing of the policy of insurance, and the outpouring of the water from the sprinklers was the inevitable consequence of the explosion of the boiler. The active and efficient cause that put in motion the water was clearly the heat from the explosion, and not the intervention of any new and independent agency.

"The explosion of the boiler was therefore the direct and proximate cause of the damage, and this cause being within the clause of the policy which insured against 'all immediate loss and damage, except by fire', the appellant [insurance company] is liable for the risks assumed under the policy. * * * Judgment affirmed with costs."

CONCLUSION

It is obvious that the foregoing case does not purport to announce any hard and fast rule on the question involved, being decided upon the particular facts of record and the language of the insurance policy sued upon. And it is further obvious that whether a particular loss under a boiler insurance policy is immediate, within the terms of a policy of this kind, will always depend upon these factors.

However, this does not detract from the force and value of the reasoning of the court, quoted at some length heretofore, as an example of how the courts construe policies of this kind. In other words, when the facts of the case are read with the language of the court in applying the law thereto, the decision at least constitutes a reliable yardstick in determining when, and under what circumstances, a loss may fairly be considered immediate within the meaning of this term as used in boiler explosion insurance.

Program of New Coal Research Laboratory of Carnegie Institute of Technology

(*Continued from page 50*)

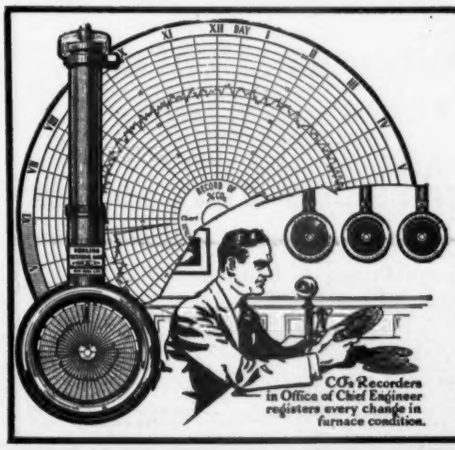
of Mines. Our efforts will be directed toward securing basic physical and chemical data which can be utilized by the men who study coal and its derivatives from the point of view of the practical man. In other words, our experts will concern themselves with the purely scientific aspects of their subject.

"By no means the least important part of the work that we shall undertake will be the training of expert fuel technologists. Graduate courses will be offered with the research staff furnishing instruction. In this way we hope to supply the need for experts in fuel technology. This work may easily prove to be the most important aspects of this new undertaking."

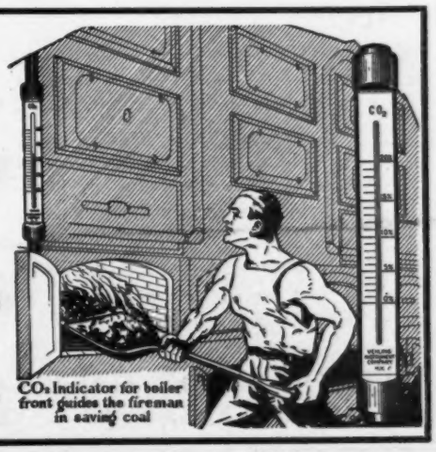
The advancement of coal research has long been a problem on which President Baker has worked. Believing that in coal research could be found the answer to many of the problems of the coal producer and consumer, Dr. Baker conceived and organized the First International Conference on Bituminous Coal at the Carnegie Institute of Technology in 1926. The success of this congress, attracting as it did some of the best scientific minds of the world, testifies as to the ability of its organizer.

A second conference in 1928 again brought forth contributions from leading scientists in America and abroad, and established the Carnegie Institute of Technology as a leader in this field. A third world-wide conference has been announced for November, 1931. President Baker plans to go abroad this winter in connection with the organization of the third meeting.

Out of his efforts in organizing these brilliant meetings came the coal research laboratory. Mr. Myron C. Taylor, chairman of the finance committee of the United States Steel Corporation, assisted President Baker in planning and organizing the laboratory.


CO_2 Recorders in Office of Chief Engineer registers every change in furnace condition.

MAKE FUEL WASTE VISIBLE
with
APEX CO_2 RECORDERS
Send for Catalog
UEHLING INSTRUMENT CO.
4 Vesper St. Paterson, N. J.


CO_2 Indicator for boiler front guides the fireman in saving coal

APEXIOR
REG. U.S. PAT. OFF.

REDUCES BOILER MAINTENANCE COSTS

The accepted protective coating

Severe pitting and corrosion is prevented in new boilers and permanently checked in old tubes and drums. Intervals between outage periods are increased, and added life is given to internal boiler surfaces treated with APEXIOR

The DAMPNEY COMPANY *of* AMERICA
Hyde Park, Boston, Massachusetts

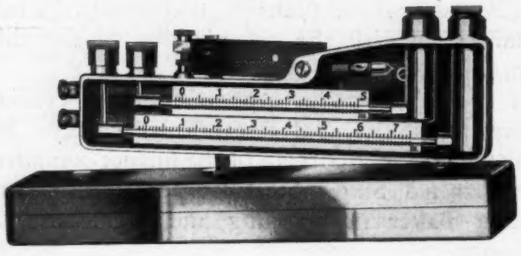
Write for Bulletin 1238

REFRACTORIES

Fire Clay
Silica Chrome
Magnesite
High Alumina (Diaspore)
High Temperature Cements

General Refractories Company
106 South 16th St., Philadelphia, Pa.
District Offices: Birmingham, Boston, Buffalo, Chicago, Cleveland, Detroit, Indianapolis, New York, Pittsburgh, St. Louis, San Francisco
Representatives: Seattle, Montreal, Havana, Cuba
4187

WHEN YOU BUY
Portable Draft Gage Sets



See

1. That the Gage is an Ellison—the genuine not an imitation. A complete line for every purpose from the domestic furnace to the super power boiler.
2. That the gage has a sliding scale, micrometer leveler and a removable plug for cleaning the indicating tube.
3. That the carrying case is of stamped aluminum—light, durable and compact.
4. That the sets are complete with the necessary attachments.

ELLISON DRAFT GAGE COMPANY
214 West Kinzie Street Chicago

Pittsburgh Piping
Creased Bends
(Patented)
SAVE SPACE
DECREASE HEAT LOSSES
Write for Literature.
Pittsburgh Piping & Equipment Co.
Pittsburgh, Pa.

NEW YORK 220 Broadway
SAN FRANCISCO Call Building
BOSTON 10 High Street
CHICAGO Peoples Gas Building
INDIANAPOLIS Occidental Building
DETROIT General Motors Building
CLEVELAND Ulmer Building
HOUGHTON, MICH. Dee Building